# DIE-CASTINGS

A manual for the user, buyer
and designer

ARTHUR STREET, Ph.D., B.Sc.

LONDON:

EMMOTT & CO. LIMITED

28 BEDFORD STREET, W.C.2

and at 31 King Street West, Manchester

1939

Made in Great Britain
Printed at The William Morris Press Ltd., Manchester

# INTRODUCTION

DURING the past twenty years die-casting has risen from the status of an interesting metallurgical novelty to a rapidly developing industry which is of very real importance to all who are users of bulk quantities of fittings. Indeed, every person who owns a car, radio, washing machine, or who lives in a modern house, is almost certain to be a user of die-castings.

There are a few thousand people in this country who are directly associated with the manufacture of die-castings but there are many times this number who, in their business, are interested in the utilisation of die-cast products. It is to the "user" that this book is directed, and it is hoped that the following pages may be of some value to those who are concerned with the design, purchase or application of die-castings. No doubt some readers may wish to investigate certain aspects of the subject in more detail, so the book concludes with a bibliography.

The writer would express his sincere thanks to Mr. C. C. Bissett, Director and Manager of Fry's Diecastings Limited, for suggestions and help, and to Mr. John V. S. Brown for the illustrations.

# CONTENTS

# TABLES



# LIST OF ILLUSTRATIONS

CHAPTER I

# Die Casting

IT is difficult to spend a day of one's life without coming in contact with the products of the die-casting process. In automobiles, household appliances, electric equipment and a continually increasing range of other modern articles in everyday use, die-casting plays a big part in making possible the bulk production of attractive and saleable commodities at low cost. There are well over half a million die-castings made every day in this country alone, and in Germany, Italy, France, Russia, Japan and America, the process is also rapidly reaching the status of a major industry.

Although much of the development of this modern method of manufacture has been due to the die-caster himself, yet the extraordinary spread of the application of die-castings would not have been possible without that important person—the "user of die-castings." It is certain that the process does not show its real value until the consumer actively co-operates with the producer in designing the component which is to be die-cast, in choosing the alloy and in deciding the most suitable finish which is to be applied.

Readers will be familiar with at least "first principles," so that it will suffice to summarise that die-casting is a metallurgical method by which castings are produced from permanent metal moulds. The external shape of the part is conferred by the main portion of the die, generally made in two halves which are closed together for the casting operation and opened for the removal of the die-casting. Holes and recessed features are produced by steel cores which are either moveable or fixed as part of the die block.

There are two widely used die-casting processes, each of which has its own special advantages and requirements. In the simpler "gravity" method the mould is opened and closed

manually, cores are inserted and withdrawn by the die operators, and the metal is poured in quite a similar manner to that used in the ordinary foundry.

The second process, which is known as "pressure" die-casting, represents an attempt to make the operation automatic and precisely controlled. The die is opened and closed by mechanical means, cores are moved in and out of position by similar methods, the alloy in the liquid or plastic state is introduced into the die under a high pressure, and the completed casting is lifted away from the mould by automatically operated ejector pins.

The process specially lends itself to the production of bulk quantities of small or medium sized metal fittings. Usually the weight of die-cast components ranges between half an ounce and ten pounds, but occasionally extremely light or very heavy die-castings have been produced. One of the smallest has been the individual component of a zipp fastener which has been die-cast in America; the largest die-castings have been used in automobile construction for such parts as crank cases, radiator grilles and windscreen frames. One of the heaviest pressure die-castings which has been made so far is the windscreen frame for a touring model of the Cadillac car; this component was in zinc-base alloy and weighed 33 lb.

The process is applied to the shaping of non-ferrous alloys with melting points ranging from about 200° C. for the tin-base alloys to over 1000° C. for aluminium bronze. It is the alloys with medium melting point and medium strength which are generally die-cast, and about 90% of production in this country is concentrated on the zinc-base alloys (with melting point of about 400° C.) and the aluminium-base alloys (melting point approximately 550° C.). These two groups combine reasonable strength, good appearance, low cost and that very important something which may be called "diecastability."

Die-casting appeals to users for many reasons, but probably the most common attraction is that for the bulk production of non-ferrous alloy parts it is frequently the least expensive method of fabrication. Manufacturers who require bulk supplies to be delivered with unfailing regularity find that the die-casting industry can meet their needs, and even where a single impression mould is used, an output of 10,000 die-castings per week is not uncommon.

People are becoming more and more conscious of the sales appeal of a carefully designed product; one has only to

compare modern electric clocks, vacuum cleaners, domestic wringers, door fittings and motor-cars with their predecessors of ten years ago to see how the use of components specially planned for die-casting has improved the appearance of these necessities.

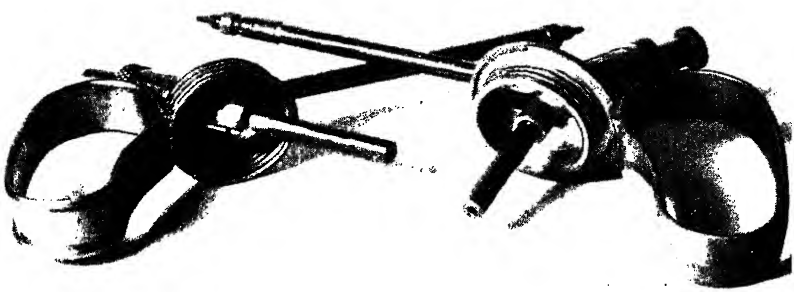


**Fig. 1.—An oil-can top before and after it was die-cast**

Fig. 1 may be interesting because it shows the top of an oil-can before and after it was die-cast.

Although an oiler is not at the best of times an ornamental thing, it was considered that by designing for its production as a die-casting, the saleability of the article could be increased. The results of making the oiler top as a one-piece die-casting more than justified the care which was put into the redesign of this part. In addition to improved appearance the manufacture was considerably simplified. Before die-casting was employed 23 operations were needed in the making and soldering together of the assembly of pressings; when zinc-base alloy die-castings were used, the only machining operations necessary were one reaming and three tapping operations all carried out in a reversible jig. A further advantage immediately became apparent—the one-piece die-casting was so solid that oil leakage was reduced to zero.

CHAPTER II

# Gravity Die Casting

At the British Museum there are axes and arrow heads of fine workmanship which were cast in the Bronze Age by the use of permanent clay moulds. Some of these bronze die-castings are quite complicated. In some cases a ring is included at the end of the arrow head so that it could be bound more securely on to the shaft; movable cores were even

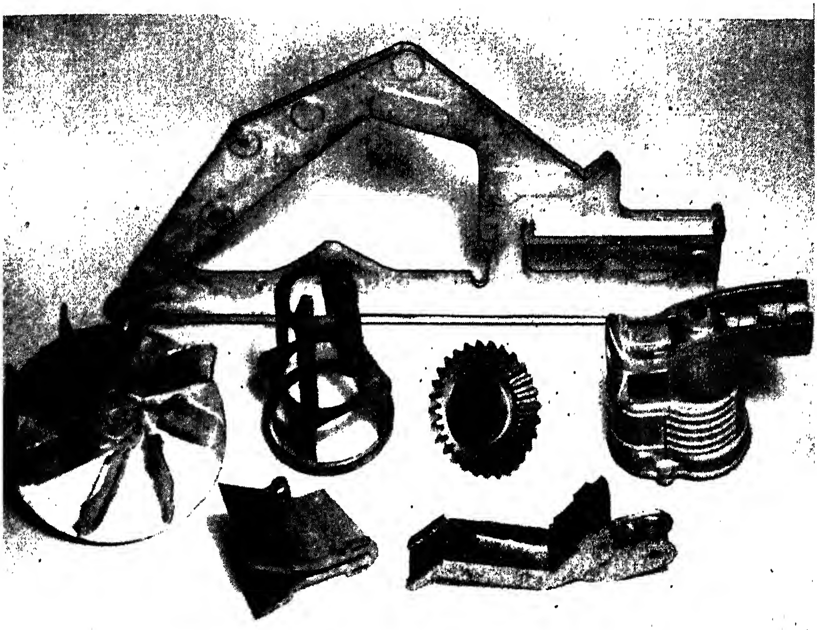


**Fig. 2.—Group of gravity die-castings** *Courtesy of Fry's Diecastings Ltd.*

used to form the socket of the axe head into which the handle fitted, and it also appears that the die-casters in those days realised that to make the alloy flow into the thin sections it was necessary to heat the mould.

Nowadays the dies are made of metal, but the liquid alloy is poured so that it runs smoothly into the mould under its own weight, just as it did 3000 years ago. In this country the process is called "gravity die-casting." The use of permanent moulds for the manufacture of castings has been for many years a feature of enterprises which require the production of bulk quantities; the motor trade is probably the biggest consumer of gravity die-castings at present, but the aircraft, electrical, and other engineering industries are using large quantities. It is estimated that in this country the simple gravity method accounts for more than half the bulk produced by die-casting. (The remainder is, of course, represented by the pressure process.)

Fig. 2 shows a group of gravity castings in which the four near the centre are of the yellow metal, aluminium bronze, and the other pieces are of aluminium alloy. Fig. 3 shows a gravity die and cores together with the aluminium-bronze shackle which was produced.

The alloy is usually melted in a gas, electric, or oil-fired crucible. Sometimes the die operator acts as his own caster, with the advantage that he can regulate the temperature of the metal to suit the special job in hand. There are other foundries where a pourer operates a large furnace and attends to the requirements of from two to four die operators.

## Grain and Porosity

Owing to the chilling effect of the die on the alloy, the grain size of gravity die-castings is fine and the product is considerably stronger than the same alloy cast in the ordinary foundry. For instance, sand-cast aluminium bronze has a tensile strength of about 20 tons per sq. in., but in the gravity cast form a strength of over 30 tons is achieved.

Although the user should realise that problems such as the change of thin section to thick will make porosity (or rather, contraction cavities) almost inevitable, yet if the section is reasonably uniform and not greater than ½ in., the user should expect his gravity die-casting to be definitely solid.

The fact that the cores are manipulated by hand can sometimes be turned to advantage in the casting of undercuts.

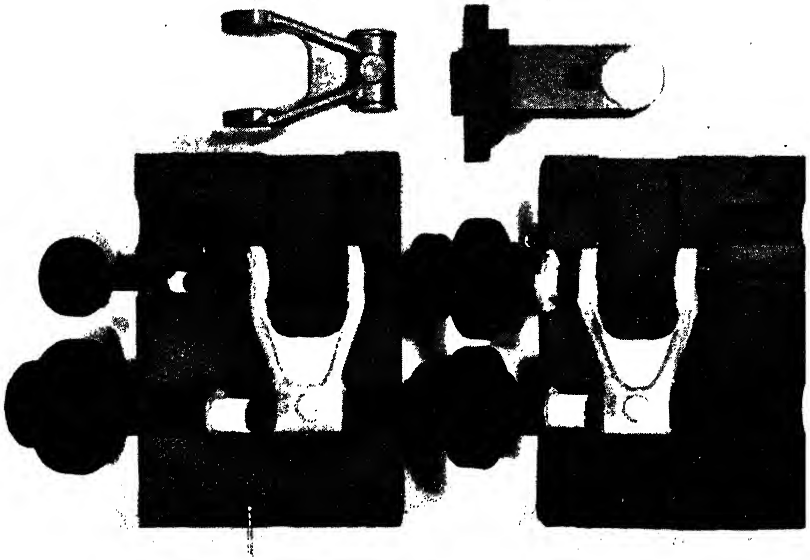


**Fig. 3.—Gravity die, with the aluminium bronze shackle produced from it**

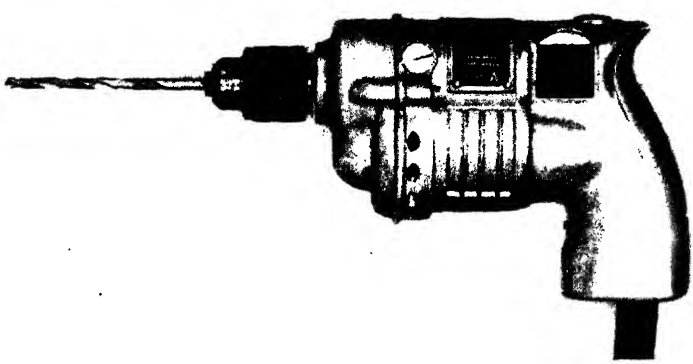
Where an internal shape is such that a solid metal core could not be withdrawn after the casting operation, it is said to be an undercut design, and the usual way of overcoming this difficulty is to construct the core in two or more sections and withdraw them in a certain sequence. The human hand is superior for this purpose to any machine where moderate quantities of castings are required. This reason makes gravity die-casting more suited than the pressure process for the production of undercut designs. A further advantage is that the gravity cast alloy has less tendency to penetrate between and lock the sections of the core.

The two halves of the mould resting on a steel bench are clamped together, cores are inserted, and the die is tilted at a suitable angle to receive the alloy. A few seconds after pouring, the various cores are levered out, the die is unclamped, and the die-casting carefully removed. Immediately after extraction the operator glances over the casting to see if it has been

completely run; in its hot condition, surface markings, etc., will not be seen, so it is put to cool before being more carefully examined. Naturally this inspection, although carried out by eye alone, is as rigorous as possible to avoid unnecessary finishing operations being done to defective work. In the trimming shop the runner is cut off and the rest of the die-casting is fettled, which may involve turning, linishing, and filing operations. Sometimes light machining operations are performed in the die-caster's works, and these are carried out before the final inspection.

After the casting has been extracted the die is dressed and assembled for the next cast. The cycle of operations takes anything from 10 seconds to 5 minutes, depending upon the size and complexity of the job. A general average production is 250 per day.

Most alloys can be die-cast by the gravity method providing they are reasonably fluid and are not weak at high temperatures. Aluminium alloys represent the biggest proportion of output, but the high-tensile yellow metal, aluminium bronze, is a good second, at least as regards tonnage. 60/40 brass, magnesium, zinc and lead alloys are also gravity die-cast.



*Courtesy of Desoutter Bros. Ltd.*

**Fig. 4.—Electric drill with gravity die-cast body**

Fig. 4 shows a well-known electric drill embodying a gravity die-cast body (which die-casting will be seen on the right-hand side of Fig. 2).

The moulds are usually made of cast iron, semi-steel, or nickel steel. The choice chiefly depends on the melting-point of the alloy which is to be cast; for instance, aluminium bronze, with a melting-point of about 1000° C., is preferably cast in steel moulds, while aluminium alloys can be die-cast in moulds of cast iron. This material has the advantage that it is not so liable to warp as steel, but its lower strength and less resistance to heat mean that it will not be suitable for casting the high-melting-point alloys. Cores are made of cast iron or alloy steel, generally the latter.

The cost of a gravity die is quite low—some simple moulds cost only a few pounds; an average figure is £10, but for complicated components £100 or more may be paid. However, essentially a gravity die is inexpensive, and as a rule it is likely that this method will prove economical when 250 or more castings are required. A tool cost of £15, for instance, represents just over 6d. per piece on a 500 basis, and very often the saving in finishing and machining accounts for more than the cost of the tool even on the first order, and of course further releases from the same die show still more saving.

Another convenience is that the cost of setting up the die each time castings are required is not great. Usually, however, a gravity die-caster prefers to deal with releases that will involve at least half a day's work in the foundry—*i.e.*, it is preferable to call for gravity die-castings in not less than 100 at a time. This raises a point which users might do well to remember: die-casters prefer to base their estimates on the quantities which will be absorbed over a period of such as six months. They do not expect to deliver the whole amount at once, so the die-caster should be asked to despatch quantities to schedule over a period.

## Accuracy

The accuracy of gravity die-casting depends largely on the skill with which the die is cut and the care which is taken to keep it in good condition. For example, in making brass gravity castings, omission to dress the mould causes a layer of zinc oxide to build up on the die face so that the product becomes rough and smaller in size.

Cores have to be attended to and renewed as soon as they begin to wear under the repeated action of the hot alloy. A well-treated mould should produce anything between 5000 and

25,000 die-castings with good surface appearance and with an accuracy on essential details to within plus or minus 0·005 in. per inch. Holes can be made to a similar accuracy, although taper of the order of 0·01 in. per inch should be allowed. Very small holes *can* be made, but it should be remembered that the slender cores forming these are liable to deterioration, and the user should think twice before specifying the inclusion of holes less than $\frac{1}{8}$ in. diameter.

CHAPTER III

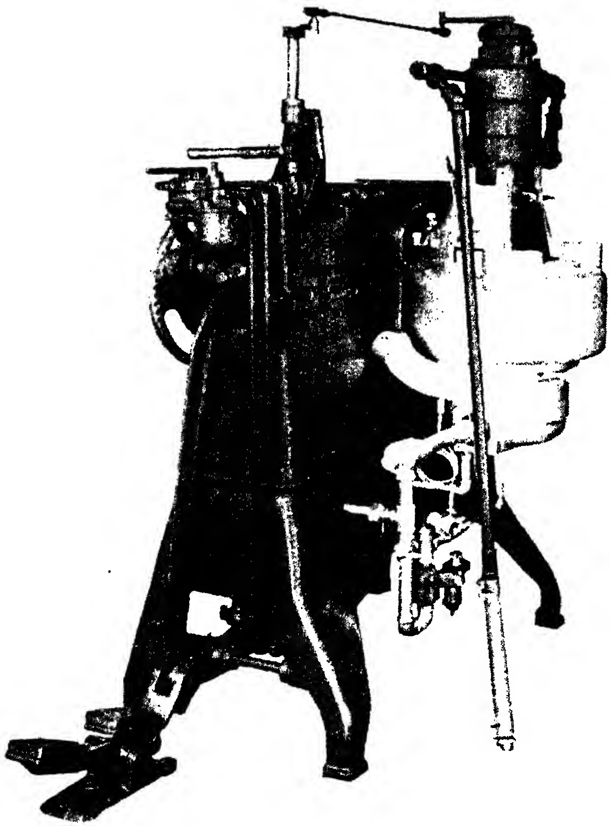
# Pressure Die Casting

THE printing industry was the pioneer of the pressure injection of liquid metal into permanent moulds. The first machine for the production of single type was made over 100 years ago and to-day the speed at which lines of print are cast makes the 1000 or so shots per day of the ordinary pressure die-caster seem almost humble by comparison. In the latter half of the nineteenth century, when it came to be realised that type-casting principles might be applied to the manufacture of articles such as bullets, toys and novelties, the methods used in printing were copied and printing metals were those which were die-cast—lead alloys containing 2% to 12% tin and 10% to 20% antimony. In early die-casting machines the injection of the alloy was brought about by a manual effort, although various devices were employed to increase the power of the injection operation. Some machines were treadle or spring operated; subsequently the casting operation was effected by a hand-operated lever working a plunger. Some of these old-fashioned "pull-bar" machines are still in use to-day for die-casting fluid alloys, such as the tin-base group.

The injection of the alloy by air pressure was introduced about 1907. The early air-operated die-casting machines had a crucible built as part of the assembly; a bent tube—usually called the "goose-neck"—was pivoted so that it could swing into the bath of metal, become filled with it and then be raised so as to come in contact with the die. A blast of air at a pressure of 50 lb. to 300 lb. per sq. in. was forced down the "goose-neck" so as to blow the liquid into the mould.

This kind of machine is usually classified as a "hot chamber" type because the injection chamber (which is part of the machine) contains molten metal necessary for several shots and the alloy is constantly held at casting temperature. In a well-

known hot chamber pressure casting machine, the Madison-Kipp (Fig. 5), the die is closed by the operator turning a spider wheel, and this action, through a toggle arrangement, also rocks the furnace assembly into the casting position. The operator next depresses a foot-lever to bring the goose-neck up to the die; this goose-neck contains the liquid metal about to be cast and connects the air supply with the mould. The foot-pedal movement has disengaged a safety catch so that the

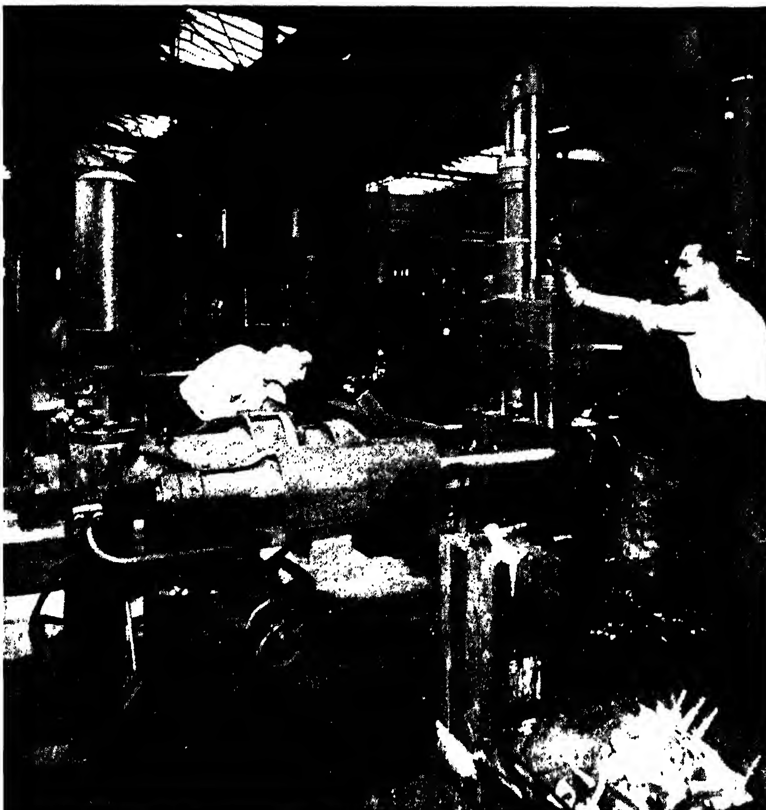


*Courtesy of Wm. Coulthard & Co. Ltd.*

**Fig. 5.—"Kippcaster" pressure die-casting machine**

operator is permitted to shift a lever which admits the compressed air into the goose-neck, thus injecting the alloy into the die. The operator then returns the valve shifting lever to its original position, unlocks the toggle mechanism and opens the die, at the same time ejecting the casting. There are, needless to say, a variety of models suitable for varying weights of castings and for different alloys. The usual working pressure of this kind of machine is 600 to 1000 lb. per sq. in.

Another class of die-casting machine is known as the



*Courtesy of Fry's Diecastings Lt*

**Fig. 6.—Cold chamber die-casting machine operated hydraulically at a pressure of 3 tons per sq. in.**

"cold chamber" type in which the alloy is melted separately and sufficient for one shot is ladled into a container which is part of the machine. On account of the high pressures which are permissible under these conditions and because of the reduced wear on the machine, owing to the comparatively short time that the hot alloy is present, the cold chamber machines are proving to be more suitable for the casting of copper and aluminium-base alloys (both types work very well with the zinc-base alloys). Fig. 6 shows a cold chamber hydraulic die-casting machine which works at a pressure of 2 to 3 tons per sq. in. The metal, in a plastic conditon, is ladled from the crucible into a cylinder where it rests on a spring-loaded piston in such a position that the metal cannot come into contact with the runner. The plunger is then forced down on to the plastic metal, thereby depressing the piston so that the alloy travels through the runner into the die. The plunger is then released and the piston springs upwards; in so doing, it cuts the sprue and ejects the surplus alloy in the form of a metallic button. This particular machine, the Polak, was originally developed to deal with the pressure casting of brass, but it has since been realised that the high pressure injection gives good results in the casting of other alloys.

Opinions vary considerably about the effect of working pressure on the quality of the die-casting which is produced, but it is generally admitted that high-pressure operation is capable of producing die-castings in aluminium alloys and in brass with almost complete absence of porosity. The zinc-base alloys which are so widely die-cast can regularly be produced solid if the working pressure is approximately 600 lb. per sq. in. and over. Of equal importance, however, is the design, construction and venting of the die, particularly the latter. Sound castings depend on the finding of the exact "balance of power" between the pressure of the incoming metal and the resistance to the escape of entrapped air.

The user should realise that not only is a pressure die-casting tool quite an expensive proposition but its setting-up is nothing like so simple as in gravity die-casting. Consequently, it is not economical to set-up for the production of small quantities only. Before the use of pressure die-casting is considered, one should be sure that at least 5000 parts will be needed and that, as a general rule, these can be taken in not less than 1000 at a time. The rate of production should be expected to be high, and once the die is working smoothly an average of over 1000 shots per

day can be obtained. (For small parts, many times this output is possible.)

Most alloys which are gravity die-cast can also be fabricated by the pressure process, but it must be remembered that in addition to the effect of the molten metal on the die we have to contend with the mechanical effect of the high-pressure injec-

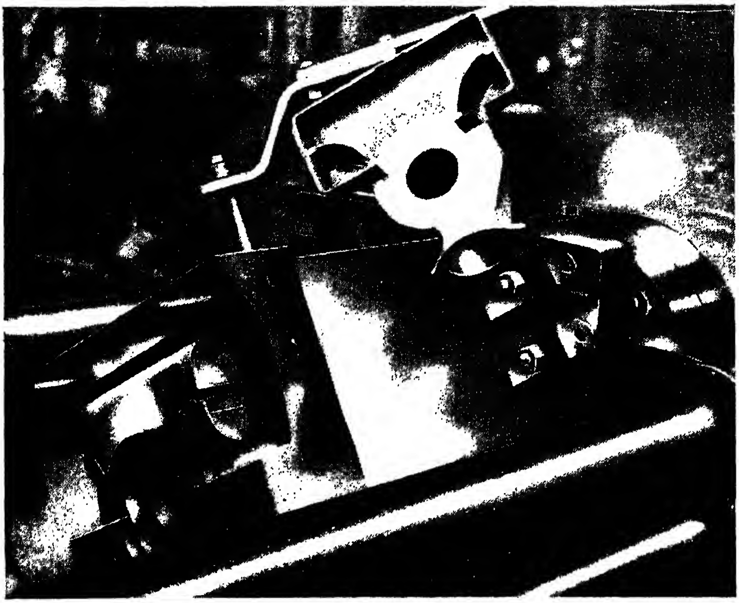


**Fig. 7.—Moveable half mould, showing also the aluminium alloy pressure die-casting**

tion of the liquid metal. Consequently, alloys with high melting points give rise to considerable problems, and it may be said that the pressure-casting of alloys whose melting point is over 1000° C. is still in the incompletely developed stage. In any case it definitely pays to see that dies used in pressure casting are extremely well made, and nowadays many pressure die-casters make a practice of hardening all tools before they are put into regular production.

Pressure die-castings are being used to a rapidly increasing extent nowadays and with each improvement in machine construction and die steel manufacture the scope of the process becomes widened. Because the human element is practically

eliminated, the pressure die-casting is almost certain to be uniform; the 50,000th casting will be an "identical twin" to the first one. Further, the pressure injection of the alloy does make the surface appearance really excellent and in some cases polishing before plating can be reduced practically to zero.

While on the subject of surface appearance the writer would suggest that the user should not be surprised if the first samples from a new die exhibit a certain amount of flow-marking on the surface, because the tool will not be running properly. But in bulk production, when the die is working smoothly at the correct temperature, the user should definitely expect his pressure die-castings to be free from seams and blemishes. It is mainly a matter of correct running and venting of the die, and if the surface appearance of a job is poor a few careful adjustments should improve matters. A personal interview with the die-caster or his representative often works wonders in bringing about an improvement in this little matter!

The accuracy which is obtainable varies with the alloy; for instance, tin-base alloys can be produced as near as no matter dead accurate, while with the zinc-base alloys, tolerance of between 0·001 in. and 0·002 in. per in. can be maintained on essential dimensions. With aluminum alloy pressure die-castings it is better not to specify under plus or minus 0·002 in. per in., and with brass pressure castings 0·003 in. per in. should be allowed.

Users of pressure castings would be well advised to make a point of becoming acquainted with the types of machine which their suppliers and would-be suppliers use, and in particular it is a good plan for responsible members of the consumer's firm to visit the die-casting works before entrusting important work to it. The size, working pressure, speed of output and usual length of die-opening of the various machines in the works can generally be ascertained with little difficulty, and from this knowledge the user can judge what are the abilities and limitations of the die-caster. For instance, it may be that the firm has a number of small, fast, automatically operated machines, in which case they would be particularly valuable as a source of supply if, say, an order were to be placed for a million tiny gears for toy manufacture. On the other hand if a large aluminium alloy pressure die-casting were required, the user should satisfy himself that the supplier can tackle such large work and produce the die-castings without porosity trouble.

CHAPTER IV

# Choice of Alloy

SIX groups of alloys are regularly die-cast and on special occasions others may be fabricated if some particular property is desired. The six main classes are as follows:

(1) Tin-base alloys—a typical composition is—

| | |
|---|---|
| Tin ... ... ... ... ... | 90% |
| Copper ... ... ... ... | 5% |
| Antimony ... ... ... | 5% |

(2) Lead-base alloys—a typical composition is—

| | |
|---|---|
| Lead ... ... ... ... ... | 85% |
| Antimony ... ... ... | 10% |
| Tin ... ... ... ... ... | 5% |

(3) Zinc-base alloys—three similar compositions are used, all containing 4·1% aluminium, but the copper content is varied from zero to 2·7%.

(4) Aluminium-base alloys. Practically every aluminium alloy which is sand-cast may also be die-cast.

(5) Brass, based on 60% copper, 40% zinc.

(6) Aluminium-bronze, based on 90% copper, 10% aluminium. The diagram on this page attempts to show a comparison of various physical properties of the six groups of alloys.

In choosing a suitable alloy, three factors have to be borne in mind:

(1) Raw material cost.

(2) Physical properties of the alloy, making it suitable for the particular job.

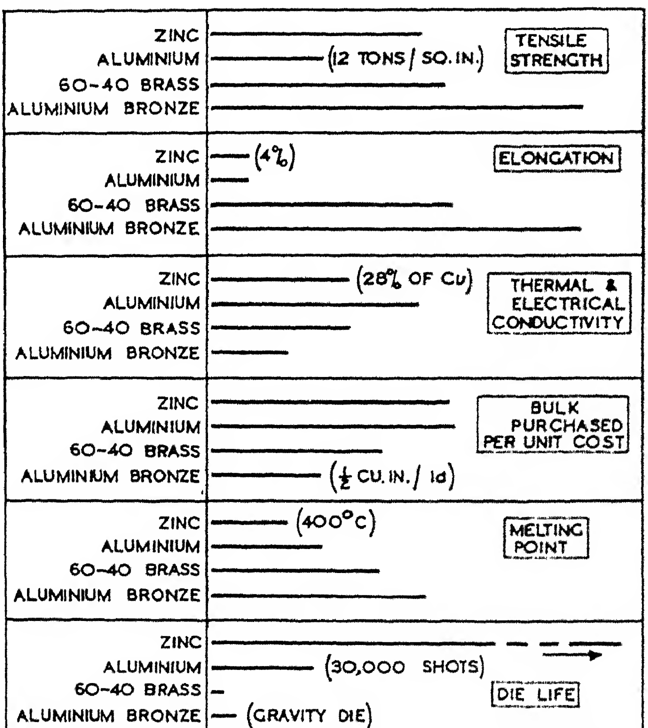
(3) Suitability of the alloy for the die-casting process.

Although the raw material cost is of some importance, the main consideration should be the cost of the finished die-casting in relation to its serviceability. Thus, for instance, iron foundry castings can be bought at about 3d. per lb., and on the face of it one would not expect, say, a zinc-base die-casting costing 7d.,

8d. or possibly 1s. per lb. to be able to replace cast iron and still show a saving. However, the bare comparison of raw material cost does not give a true guide because (*a*) by using the die-casting most or all machining operations will be dispensed with; (*b*) usually the strength of a die-casting will be greater than that of cast iron (for instance, zinc-base alloy is about twice as strong); (*c*) thick section is not necessary to the die-caster and so the weight can be reduced if required. A section $\frac{1}{16}$ in. thick can be die-cast but it would be very difficult to make cast iron of such light section—there are many zinc-alloy die-castings which are only half the weight of the iron castings which they have replaced; (*d*) although metal is usually bought

TABLE I

**Diagrammatic comparison of some important properties of die-casting alloys**



by the "pound," one does not buy vacuum cleaners or motor carburettors by the pound but at so much per article, consequently, if it is possible to use an aluminium alloy for a job, although material cost may be high the weight of the finished part will be so light that the actual cost will be reasonable; (*e*) because it is the finished die-casting which is produced, the problem of machine scrap in the user's own works does not arise.

In choosing a suitable alloy the user can generally decide which would be preferable from his own point of view, but it always pays to inform the die-caster exactly what function is allotted to the part which is to be die-cast. Questions such as the following should be answered:

(1) **What stress will the die-casting have to withstand?** Usually a die-casting will be stronger than the same alloy in the sand-cast condition. Nowadays, die-castings should definitely be expected to be close-grained and free from porosity, so that the die-cast article may be used under highly stressed conditions. If the loading is severe aluminium bronze may be preferable, but even the zinc-base alloys have been used for driving gears and parts of an electric hoist.

(2) **Will the article be subjected to shock loading?** If suddenly applied or repeated stresses of the order of several tons per square inch are to be expected, the die-caster will probably recommend that the softer white metals are not employed, but that aluminium bronze, with its high resistance to fatigue, is used. At the same time it is worth emphasising that the zinc and aluminium base alloys will stand a considerable amount of shock loading, sufficient for normal purposes. Further, if any local stress has to be borne, the die-casting may usually be designed to give increased strength.

(3) **Does the part work in any specially corrosive conditions?** Very often an alloy will be attacked by one medium and resistant in another corrosive agent; thus, for instance, a zinc-base alloy would not be used in the presence of acid, but it would be completely satisfactory when used in contact with soapy water or oil. Similar remarks apply to the other die-casting alloys.

(4) **Does the part have to be soldered?** Because most of the die-casting alloys contain aluminium their soldering is difficult, although there are compounds on the market which claim to have overcome the difficulty. It should be remembered, however, that by the use of die-casting one can usually avoid

soldering operations and a part which was previously made in two components which were soldered together can frequently be designed as a one-piece die-casting (see page 99).

(5) **Must a special finish be applied to the die-casting?** A wide range of attractive finishes can be applied but the treatment which has to be given will depend on the alloy. For instance aluminium, zinc-base alloy and brass cannot be plated by exactly the same method, and an oxidised copper finish would not be applied to a zinc-base die-casting in the same way as to brass or aluminium bronze.

Both the user and his die-caster must decide whether the alloy will be suitable for production by die-casting. They must consider the thermal effect and the erosive effect of the alloy on the die steel. If, for instance, it were attempted to die-cast pure zinc, the metal would quickly galvanise the steel, but by adding 4% aluminium to the zinc the solvent effect is completely prevented; this is one of the reasons why all zinc-base alloys contain approximately 4% aluminium.

The alloy must not be hot-short, otherwise it will crack while still hot. In making foundry castings the sand mould will "give" under the contraction of the metal, but in die-casting the alloy contracts under the constraint of a rigid steel mould with possibly several cores in position. If commercial 70/30 brass, which is weak at a temperature just below its melting point, is die-cast it will crack, but on the other hand 60/40 brass can be die-cast with success because it is reasonably ductile at high temperatures. Because of their high melting points or hot shortness, gunmetal, phosphor bronze, Monel metal and steels are not really suitable for die-casting.

For obvious reasons the melting point of the alloy has a considerable effect on the life and serviceability of the die. Further, the higher the melting point the less the intricacy which can safely be included in the die-casting. Automobile carburettors, sometimes of extreme complexity, are produced as pressure die-castings in zinc-base alloy and a die life of several hundred thousand shots is achieved. If such a mould were used to produce a brass pressure die-casting, the effect of the alloy on the intricate die and numerous slender cores would be to make it break down after about half a dozen shots.

CHAPTER V

# Zinc-Base Alloy Die-castings

ZINC-BASE alloys are essentially a development of the die-casting industry, and it is in the pressure-cast form that their value is shown to its maximum. To a remarkable degree the zinc-base group combine ease of die-casting, good appearance, convenience of finishing, cheapness, ample strength and hardness. About 12,000 tons were consumed in 1936 in this country, and the quantity is rapidly increasing each year, so that at the present time (1939) we are probably approaching the 20,000 mark. The U.S.A. with three times our population consumes nearly five times as much zinc-base alloy as we do, so this may indicate that still larger quantities will be used here in coming years.

Unalloyed zinc can be die-cast if it is of very high purity and the design of the part not too complicated, but the pure metal will tend to galvanise the die because iron and steel dissolve in the molten metal. If about 4% of aluminium is added to the zinc it will be prevented from taking iron into solution, and so the alloy can be die-cast continuously without any fear that the mould will be dissolved away. It so happens also that the alloy with 96% zinc and 4% aluminium has the best mechanical properties of the zinc-aluminium alloys.

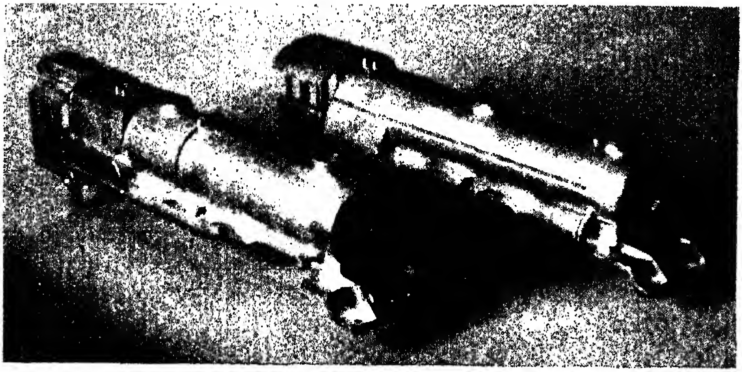
If copper up to 2·7% is added to the zinc-aluminium alloy, the ternary alloy is considerably harder and stronger but it is not so good in its permanent resistance to impact. However, there is an advantage of the copper-containing alloy; it is easier to cast, and the general opinion is that solidity is rather more readily achieved in the copper-containing alloy than in the copper-free one. Table II gives some properties of three zinc-base alloy compositions which are widely die-cast in this country and all over the world.

A good many years ago it was suspected that these alloys were likely to be of considerable value. but in the 1920's. using

the zinc which was then available, the zinc-base alloys were found to suffer from a serious defect. They were not permanent. They changed in dimensions and became brittle after being in use for some time. Sometimes they even completely disintegrated!

The die-casting industry owes a very real debt to the New Jersey Zinc Company, of America, for its work in improving the zinc-base alloys. The research workers of this company showed that the alloys were not inherently unreliable, but that they owed their apparent defects to the presence of minute traces of tin, lead and cadmium which were contained in the spelter. As little as 0·05% of tin was enough to spoil the alloy.

This company developed a process whereby zinc of greater than 99·99% purity was obtained. Once this was employed, the zinc-base alloys came into their own. These advancements occurred between the years 1929 and 1932, and since then the



*Courtesy of Trix Ltd.*

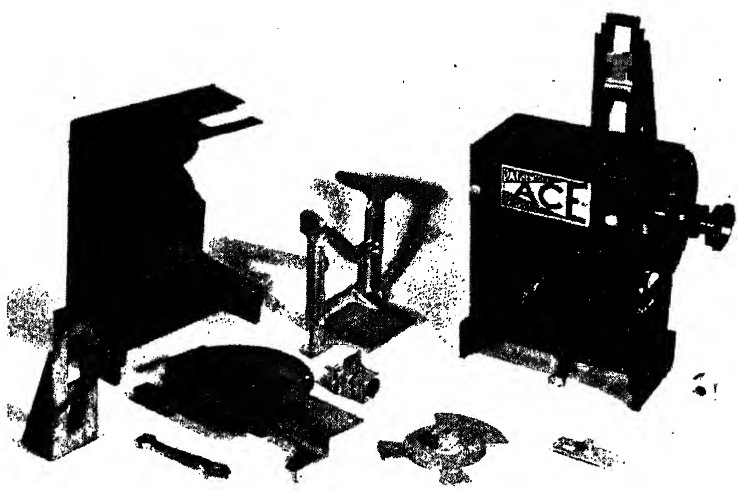
**Fig. 8.—Model locomotive bodies pressure die-cast in zinc alloy**

progress of zinc-base die-casting has gone forward by leaps and bounds. It is not often that one wants to tie a knot in a zinc-base die-casting, but it is comforting to know that under suitable conditions this could be done, for it indicates that the alloy includes ductility with its other mechanical properties.

Even in the days when die-castings were made using spelter of less than 99·8% purity, it was realised that an improvement could be effected if between 0·01% and 0·1% of magnesium were added. To-day a small magnesium addition is still made—

usually about 0·03%. The effect of the magnesium is not conclusively understood, although a great deal of research has been done on the subject (it is not that we do not know what effect the magnesium has, but there appear to be about four different effects occurring together. The difficulty is to decide which of these is the most essential and important). It is certain, however, that a small addition of the order of 0·03% of magnesium assists in making the die-casting permanently stable, but that too much must not be added since 0·1% or more causes the alloy to be "hot-short."

As will have been seen from the table, there are three compositions which are in wide use, and generally the alloy is selected from these three, according to the application for which the die-casting is intended. If the component must be hard




*Courtesy of Pathescope Limited.*

**Fig. 9.—An example of one product built up from a number of zinc-base die-castings**

and strong, the maximum copper content of 2·7% is included. If the part has to be ductile or to stand repeated stresses over long periods, the copper-free alloy will give better service. The intermediate alloy with 1% copper is becoming increasingly popular; it combines the ease of casting and most of the tensile strength of the high-copper alloy, with the almost complete

maintenance of impact resistance which is possessed by the copper-free alloy.

Immediately after casting, the alloys all undergo a very slight contraction which takes place over a period of several weeks, and which is of the order of 0.003 in. per in. For most purposes this is not an important dimensional change, but for very special uses, such as components of optical equipment, the copper-free alloy is used and a low temperature anneal should be given which causes the contraction to occur before the component is put into service. Three hours at 100° C. will be ample to stabilise the die-casting.

If the alloys are exposed to the prolonged action of steam they show subsequent enlargement. The copper-free and the 1% copper alloys only expand by a fraction of a thousandth of an inch, but the 2.7% copper alloy expands several thousandths, at the same time considerably losing in impact strength. Therefore, if a zinc-base die-casting is to be used at elevated temperatures, particularly in the presence of moisture, the low-copper alloys should be selected.

Although these points must be borne in mind, it should be stressed that for most purposes the dimensional changes are not serious because they are so small. In any case, zinc-base die-castings, whatever their treatment, remain considerably less brittle than, say, cast iron. "Age hardening" is not a thing peculiar to zinc-base alloys. Subsequent dimensional and hardness changes occur in practically every alloy that has been rapidly cooled from a high temperature to a low one.

The zinc-base alloys can be finished in a multitude of ways; they can be nickel and chromium plated, treated with dozens of chemical finishes, enamelled, lacquered, covered with plastic.

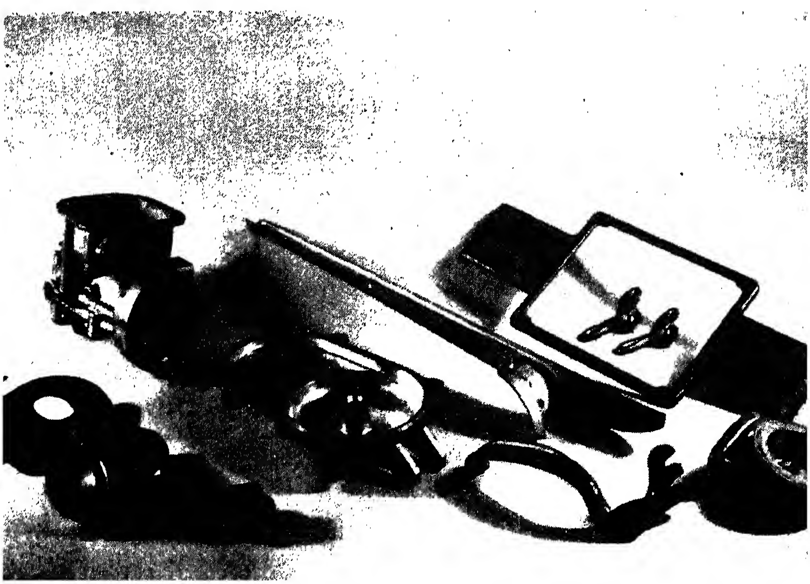
TABLE II PHYSICAL PROPERTIES OF THREE ZINC-BASE ALLOYS

| | Mazak No. 2 | Mazak No. 3 | Mazak No. 5 |
|---|---|---|---|
| | per cent. | per cent. | per cent. |
| Composition : | | | |
| Aluminium ... ... ... | 4·1 | 4·1 | 4·1 |
| Copper ... ... ... | 2·7 | — | 1·0 |
| Zinc of 99·99 purity and about 0·03 Magnesium ... | Balance | Balance | Balance |
| Tensile strength ... ... | 19—21 tons | 15—17 tons | 18—19 tons |
| Elongation on 2 ins. ... ... | 3—8 per cent. | 2—5 per cent. | 3—6 per cent |
| Brinell Hardness ... ... | 83 | 62 | 73 |
| Impact strength (as cast) ... | 19 ft./lbs. | 20 ft./lbs. | 17 ft./lbs. |
| Impact strength (after 10 days in steam) ... ... ... | 1 ft./lb. | 20 ft./lbs. | 11 ft./lbs. |
| Electrical conductivity : | | | |
| Copper 100% ... ... | 26 per cent. | 27·5 per cent. | 27 per cent. |
| Weight per cubic inch ... ... | ·25 lb./cu. in. | ·24 lb./cu. in. | ·25 lb./cu. in. |
| Melting point ... ... ... | 379·3° C. | 380·9° C. | 380·6° C. |

Indeed, the number of finishes which can be attractively applied to zinc-base die-castings seems almost as limitless as the number of uses to which these die-castings can be put.

As regards cost, readers will probably know that when bulk quantities are required, zinc-base die-casting is frequently the cheapest method of producing a metal fitting. Although the cost is low, the strength and good appearance attain a high level. The actual price of a die-casting varies with the size and weight of the part, with the quantities which are to be consumed, and also with the complexity of the component. There are some zinc-base die-castings which cost less than 6d. per lb., but there are others which work out at well over 1s. per lb. [Incidentally, die-castings are practically never sold on a "per lb." basis but, because each die-casting has its own special problems, they are sold at so much per casting.]

It should be remembered that in nearly all cases it is possible

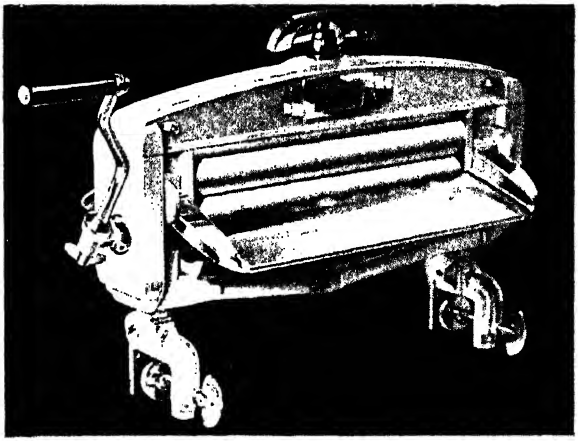


*Courtesy of Fry's Diecastings Ltd.*

**Fig. 10.—A group of zinc-base die-castings which gives a hint of the variety of purpose served. Included in this one picture are castings for the motor, cycle, wireless, and building trades**

to produce the finished article when zinc-base alloys are die-cast. Very small holes—down to $\frac{1}{32}$ in. diameter—can be cast if required; external and internal threads can be produced if the user is quite sure that it is cheaper to die-cast them than to cut them in the usual manner. If it is desired to reduce weight, the section can be brought down to $\frac{1}{16}$ in. or even less if the part is small. The writer is familiar with several cases where the weight of a zinc-base die-casting has been less than half the iron casting it replaced.

The general accuracy of zinc-base die-castings should be expected to be of the order of 0·001 in. per in. on essential dimensions. A taper is usually required on holes so that the



*Courtesy of Acme Wringers Ltd.*

**Fig. 11.—Domestic wringer embodying many zinc alloy pressure die-castings**

core pins can be pulled without disfiguring the casting, but this taper usually only has to be about 0·002 in. per in. If the die is well made and carefully hardened it should produce zinc-base die-castings for several hundred thousand shots, and under ideal conditions a die life of over a million shots can be obtained.

Figs. 8 to 11 illustrate some of the uses of the zinc-base alloys. In Fig. 8 the L.M.S. and L.N.E.R. locomotives have been reproduced in a way which will satisfy even the acute engineering mind of a modern schoolboy. Fig. 9 is a well-known home cinema projector with the various zinc die-castings

which feature in its construction. Practically every small hole has been accurately cast. Fig. 10 is a group showing die-castings as applied to the manufacture of automobiles, petrol engines, cycles, radio and casement fittings. Fig. 11 shows a well-known domestic wringer which has been specially designed with die-castings in mind; indeed, practically every metallic fitting is a pressure die-casting. Compare this attractive machine with an old-fashioned cast-iron wringer and it will be appreciated how the use of die-castings has improved sale-ability, appearance and efficiency.

CHAPTER VI

# Aluminium Alloy Die-castings

ALUMINIUM alloys are both gravity and pressure die-cast, the former process accounting for the larger output at present. There are three reasons why there are not so many aluminium alloy pressure die-castings used in this country: firstly, a number of designs which are gravity cast are not at the moment commercially "die-castable" by the pressure method. Pistons, for instance, are so considerably undercut that the hand-operated gravity die-casting process has to be applied. Again, automobile crankcases are so bulky that there are very few pressure casting machines in this country which can tackle them. Both these components, however, are likely to be pressure cast before many years are past.

The second reason is that there is considerable technical difficulty in producing *solid* aluminium alloy pressure die-castings—certainly it is more difficult to obviate porosity in aluminium-base than in zinc-base alloys. But it can be done, and if a casting pressure of from 2 to 3 tons per sq. in. is applied under experienced direction, a light alloy pressure casting can be made even more solid than a gravity casting.

The third reason is that there is quite a number of engineers in this country who have just not realised that they could get improved results by the use of aluminium alloy in its pressure die-cast form. However, it is likely that users will, in the coming years, realise more and more the value of aluminium alloy pressure die-castings for the bulk production of light metal fittings, and we may expect the output of pressure castings to exceed that of the older process. Figs. 12, 13 and 14 indicate the kind of jobs which are being pressure cast with considerable success.

The aircraft, automobile, telephone, and domestic appliance

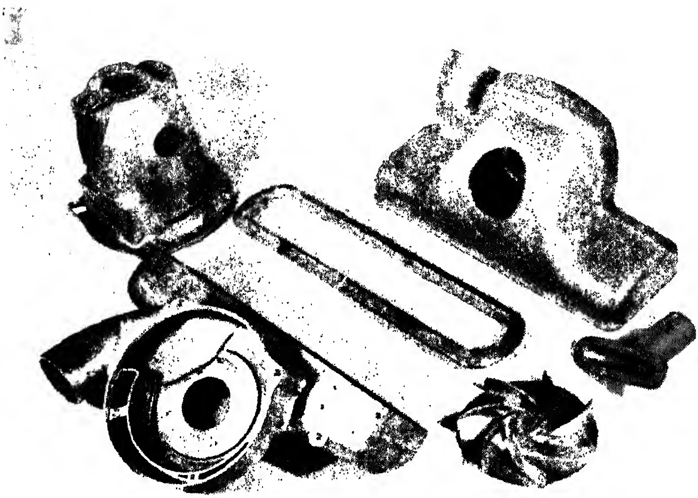


**Fig. 12.—Group of aluminium alloy pressure die-castings as applied to the manufacture of vacuum cleaners**

industries owe much to the use of aluminium alloy die-castings, and it is certain that the ownership of domestic machinery would be very small were it not for the economies of mass-production which can be brought about by the use of light alloy die-castings. Another feature which is not always appreciated is that by using die-castings, the section of the part can be reduced so as to diminish the weight still further and thus to accentuate the lightness of the article. Fig. 13 shows a pair of pressure cast binocular bodies in which the ruling section has been reduced to $\frac{1}{16}$ in.; the weight of the pair is only $4\frac{1}{2}$ oz. although the binoculars are $4\frac{3}{4}$ in. long.

Pure aluminium can be die-cast, but owing to the weakness of the metal at high temperatures, so far it is only possible to die-cast simple shapes. If there were too many cored holes or complexities, the parts of the die would pull on to the contracting casting and cause cracks to appear. However, subject to this reservation, there seems to be a good future for this class of work; for instance, it is quite possible that pure aluminium saucepans for use with modern stoves may be pressure die-cast

in the coming years. At the moment the most interesting application of the die-cast pure metal is the production of rotors, where aluminium conductor elements are pressure cast into a framework of soft iron laminations. This will be discussed later (page 82).

Usually, of course, the aluminium is die-cast in the form of some alloy. Silicon, copper, iron, zinc, nickel, or magnesium may be added, according to the properties which are desired.

TABLE III.—PROPERTIES OF SOME WELL-KNOWN DIE-CASTING ALUMINIUM ALLOYS

| Alloy | Major constituents (Balance Aluminium) | | | | | | Mechanical Properties in the die-cast form | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cu % | Si % | Zn % | Fe % | Ni % | Mg % | Tensile Strength Tons per sq. in. | Elongation in 2 in. % | Brinell Hardness |
| L.11 ... ... | 7–8 | | | | | | 9 | 3 | 55– 60 |
| L.8 ... ... | 12 | | | | | | 9 | 1–2 | 75– 80 |
| L.33 ... ... | | 12 | | | | | 12–13 | 3–6 | 55– 65 |
| L.5 ... ... | 3 | | 13 | | | | 11 | 3 | 60– 70 |
| Y. alloy (L.24) ... ... | 4 | | | | 2·0 | 1·5 | | | |
| | (usu | ally | trea | ted | after | | | | |
| | cast | ing) | | | | | 18–20 | 2 | 95–100 |
| 'Birmabright' DTD.165 ... | | | | | | 3–6 (plus 0·25 to 0·35 Mn) | 11 | 5 | 55 |

Table III shows the composition and properties of some alloys which are die-cast. As a matter of fact, it is quite likely that there are too many aluminium alloys specified at the moment. Except for special purposes where some particular heat treatment is necessary, the die-casting aluminium alloys could be reduced to about three in number, and indeed, the writer is quite sure that for the manufacture of pressure die-castings practically every part could with advantage be made using the alloy with 11-13% silicon. This alloy is specially useful because it combines resistance to corrosion with comparatively high strength and ductility in its die-cast form.

While on the subject of the aluminium-silicon alloy, an interesting phenomenon might referred to. If a foundry casting is made in a 12% silicon-aluminium alloy, the result will be both weak and brittle; looked at under a microscope, it can

be seen that the grain is of a coarse, laminated structure. If, however, a fraction of 1% of sodium is added to the molten alloy just before the metal is poured, a change takes place which is known as "modification." The strength and ductility are increased to an outstanding extent, and the grain is so much refined that you would not recognise it was the same alloy.

Probably in the next few years we shall really understand what causes this change to occur, but in the meantime it is extremely useful for die-casters that in its pressure die-cast form the alloy takes on the "modified" structure, and in its gravity die-cast condition the structure is a kind of half-way

*Courtesy of Ross Limited*

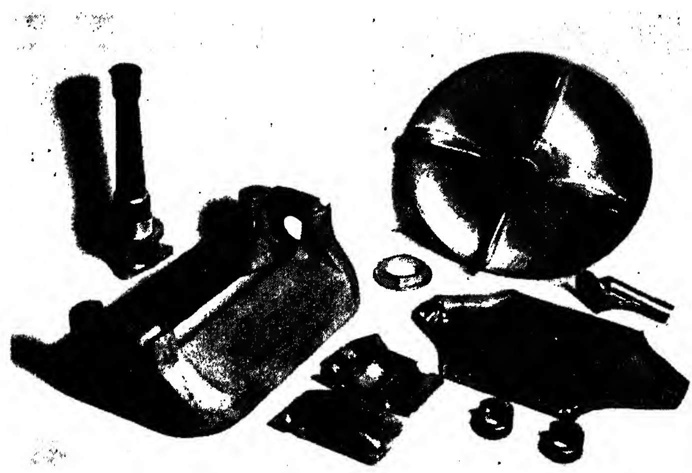
**Fig. 13.—Pressure die-cast binocular bodies in aluminium-silicon alloy**

house between modified and normal. This, of course, takes place without the addition of sodium. Consequently, although the raw material cost of this aluminium-silicon alloy is 30% more than that of the so-called "commercial" alloys, it is becoming more and more used owing to its excellent physical properties in the die-cast form.

For many reasons aluminium alloys are not "child's play" to die-cast. The metal tends to cling to the die and to the cores, and this, coupled with high contraction, means that very

generous taper must be allowed on all cored holes and recesses parallel to the die movement. A draft of from 0·01 in. to 0·03 in. must be allowed. Usually it is unwise to die-cast threads in aluminium alloys, and small holes of less than ⅛ in. diameter should not be attempted unless there is some special reason for doing so and the user realises that the small cores producing such holes will have to be renewed quite often. It is in these days very simple and very quick to drill and tap aluminium, and users are tending to apply the die-casting process with discretion.

While on occasion one can take risks in purchasing from a zinc-base die-caster who quotes an attractive price, one should be very sure indeed of the reliability of a firm who is proposing to make aluminium die-castings using the pressure process. When quantities of 5 up to 10,000 are the maximum required, the gamble of using a lightly built die on a machine working at a low pressure may come off. But when large-scale production



*Courtesy of Hotpoint Electric Appliance Co. Ltd.*

**Fig. 14.—Aluminium silicon alloy pressure die-castings for washing machines**

is wanted over a long period, it always pays to start with well-made dies operated by a high-pressure machine in the foundry of a die-caster experienced in the ways of aluminium. Only in this way can a regular supply of sound, accurate castings be

ensured without risk of delay caused by irritating petty breakdowns.

A user who is contemplating purchasing aluminium alloy pressure die-castings should make sure, firstly that the die-caster has a really good toolroom with facilities for the controlled heat treatment of the special steel dies, and secondly that the die-caster is employing machines which are of sufficient power to ensure that the casting shall be solid.

CHAPTER VII

# Brass Die-castings

IF 60/40 brass melted at 400° C. instead of 920° C. it would be as easy to die-cast as a zinc-base alloy. The higher melting point, however, brings into prominence the question of "die life," and even to-day the user of brass die-castings must anticipate that a new tool might have to be made about every ten to twenty thousand shots. Incidentally, if orders are continuous, most die-casters do not make a separate charge for the cost of second and subsequent dies, but the expense of renewal is bound to be contained somewhere in the cost of the brass die-castings.

For many purposes where the high melting point, ductility, corrosion resistance, colour or the ability to be soldered of the metal are important, brass die-castings are used, and the annual output in this country is several thousand tons. In Germany and America the production is two or three times greater than ours.

## Composition

Brass may either be gravity or pressure die-cast. The composition is usually based on copper 60%, zinc 40%, but for special alloys, silicon up to 4·5%, tin up to 1·5%, small amounts of aluminium or nickel may be added. The 60/40 composition has a double advantage in that it is ductile at high temperatures and it has about the lowest melting point of the commercially usable brasses; 70/30 brass, on the other hand, has a melting point nearly 50° C. higher and also in its commercial form it is not ductile at temperatures near its melting point. Incidentally the writer suggests that using extremely pure grades of copper and zinc, a 70/30 composition could be produced which would not be "hot short," and so could almost certainly be die-cast if a die steel suitable to its higher melting point were available.

The gravity die-casting of brass depends for its success on many factors, but the mould dressing is one of the most vital. As would be expected, the molten alloy gives off a vapour of zinc which quickly oxidises, and unless the die is dressed frequently, the zinc oxide builds up on to the mould face a hard skin which reduces the accuracy of the product and deteriorates the surface appearance. Consequently this oxide must be removed at frequent intervals, and so the die and cores are immersed after each cast into a solution containing graphite in suspension or some chemical inhibitor. The bulk of brass gravity die-castings produced under competitive commercial conditions weigh betwen 4 oz. and 24 oz., but these limits may be extended in special cases, and gravity die-castings weighing nearly 20 lb. have been produced in England. The accuracy obtainable is from plus or minus 0·005 in. to 0·007 in. per inch. In this country there are somewhere between 1000 and 1500 tons of brass gravity die-castings made every year and needless to say the output is rising.

In pressure die-casting, the problem of zinc oxidation is not so serious, because the high casting pressure reduces the tendency to vaporise (just as if water is heated under pressure of several atmospheres it will not boil so readily as an ordinary kettle on a gas stove). The combination of pressure injection and high temperature in pressure die-casting is so considerable that if the alloy were cast in its liquid state few die steels would stand more than several hundred injections.

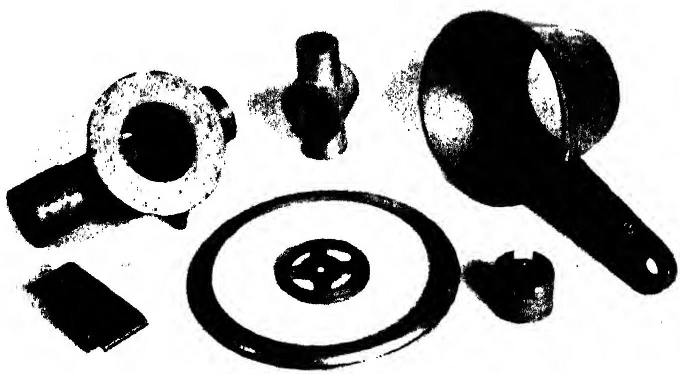
## Freezing Range

Like most alloys, brass does not solidify at one definite temperature but passes through a "freezing range" during which it is partly liquid and partly solid; 60/40 brass commences to melt at about 880° C. (this is usually called its "solidus" temperature), and it is completely melted at about 920° C. (its "liquidus" temperature). During the range between solidus and liquidus the alloy becomes more and more liquid as the temperature is increased.

About 1927, Josef Polak, of Prague, introduced a method whereby brass could be pressure cast at a temperature below its liquidus. By this means the alloy could be cast at about 50° C. lower than would have been necessary using the die-casting machines of that time, and on account of this lower casting temperature the wearing effect on the die could be substantially reduced. Polak realised that if the metal were to be injected in

this half solid, half fluid condition, it would be of no use to employ the medium casting pressures which had hitherto been customary. He developed a machine in which a hydraulically operated plunger forced each shot of metal into the die. The distance through which the metal travelled under pressure was very short and the pressure used was about three tons per square inch. By this invention the production of satisfactory brass pressure die-castings was achieved for the first time as a commercial proposition, and to-day this type of machine is used all over the world. A Polak machine has already been illustrated in Fig. 6.

For brass pressure die-castings, very many die steels have been tried and the perfect material has not yet been discovered. The casting temperature is higher than the softening range of



*Courtesy of Fry's Diecastings Ltd.*

**Fig. 15.—A group of pressure die-castings in 60/40 brass**

most steels so that a "red-hard" tool steel is essential. At the present time compositions with carbon 0·3% to 0·4%, tungsten 8% to 15%, chromium 2·75% to 3·75% are widely used. The mould is, of course, cut in the soft state and is subsequently hardened to about 440 Brinell. The heat treatment is of extreme importance; if the metal is made even a few points

too hard its shock-resistance is not adequate, and if it is too soft heat checks will rapidly appear.

The die life varies with the size, weight and wall section of the article, and anything between 3000 and 50,000 shots may be achieved. Usually after about 15,000 shots, faint hair-cracks appear on the die and these become reproduced on the castings. If these tiny blemishes are not detrimental, then the die may go on working for as many as 50,000 shots. Some parts, for instance, the block around the sprue, may have to be replaced once or twice during the life of the die, and users should, of course, realise that a tool producing brass pressure castings is working under really severe conditions. Very often the die has to operate continually at a dull red heat.

As will be seen from Fig. 15, quite complicated brass pressure die-castings can be achieved, but there are certain "rules and regulations" which an intending user should bear well in mind. The section should be as uniform as possible; a general wall thickness of $\frac{1}{8}$ in. is ideal, although if need be the section can be reduced to $\frac{3}{32}$ in. A thick section means local overheating and consequently abbreviated die life.

Small holes should not be cast; it will be appreciated that the continual impingement of the alloy at high temperatures on slender cores becomes a more than serious problem. Usually only holes greater than $\frac{3}{16}$ in. diameter should be attempted. A taper of 10 to 15 thou. per in. should be allowed. Complexities such as threads, undercuts or letterings are dangerous to attempt, and it is far better if a user makes up his mind not to call for such complexities in brass die-castings in general and brass pressure castings in particular.

Because of the attention which has to be given to the die, brass die-castings do not offer the same relative savings as pressure die-castings in other alloys. For a simple part, a sand casting or a hot brass stamping may prove to be cheaper. However, because of the accuracy of the die-cast product and because cored holes can be produced in, so to speak, three dimensions, brass die-castings have a very definite field of application which no designer can afford to ignore.

CHAPTER VIII

# Aluminium Bronze Die-castings

AN alloy with 94% copper and 6% aluminium is as strong as a low carbon steel and about twice as ductile. With 10% aluminium and 90% copper, the alloy in its die-cast state is as strong as a medium carbon steel and couples its 35 tons per sq. in. tensile strength with an elongation of 35% on 2 in. An alloy with aluminium 13% and copper 87% is more brittle than a carrot and of rather less use. This bare statement of the properties of the copper-aluminium alloys indicates that the aluminium-bronze series is, to say the least, interesting.

The reason for the outstanding variation in properties with increasing aluminium content is that in aluminium bronze the aluminium and copper exist in a state of "solid solution," and

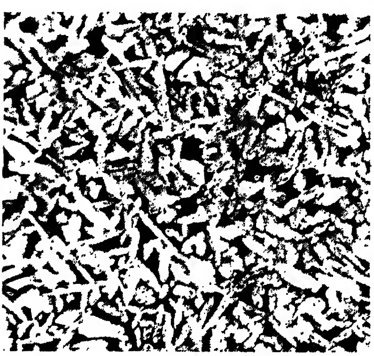


**Fig. 16.—Structure of die-cast 10% aluminium bronze (× 100). The α phase is the light constituent and the β is dark**

copper will not hold very much more than 7% of aluminium in solid solution. For instance, in an alloy with 10% aluminium, microscopic examination shows that the alloy consists of the primary solution mentioned above plus another separate phase

which can be regarded as a different solution, richer in aluminium. In common with usual metallurgical practice, the first solution is called "alpha" ($\alpha$) and the second phase is called "beta" ($\beta$). Fig. 16 shows the structure of a die-cast 10% aluminium bronze magnified a hundred times. The $\alpha$ phase is the light constituent and the $\beta$ is dark.

The $\alpha$ solution is soft and ductile while the $\beta$ is hard; consequently, up to a certain point, the more $\beta$ which is present in the alloy the stronger and tougher it will be. If, however, the aluminium content is increased past 12% a complete change takes place and a very brittle constituent called "delta" ($\delta$) comes on the scene. This is so brittle that even when small amounts of $\delta$ are present the alloy becomes quite useless, and so it is vital that the die-caster accurately controls the composition of his aluminium bronze.

Another interesting point about this series of alloys is that the proportion of the various constituents in the solid state depends on the temperature and the rate of cooling. Thus at 900° C. an alloy with 10% aluminium contains $\alpha$ plus quite a considerable amount of $\beta$. But if the same alloy is slowly cooled down to room temperature the copper is enabled to hold more aluminium in solution and consequently such an alloy would be made up mainly of the soft and ductile $\alpha$ solution. If the alloy at 900° C., containing $\beta$, is very rapidly cooled, it does not have time to absorb any more aluminium into solid solution, and so a quenched 10% alloy is made up of a background of ductile $\alpha$ solution interspersed with particles of the hard $\beta$ constituent. The physical properties of such an alloy would be extremely good because it combines the ductility of the matrix with the hardness and toughness of the $\beta$ phase.

How does this effect the die-casting industry? Because an alloy which is die-cast chills in contact with the wall of a steel mould, its cooling is rapid and indeed it is almost as though the alloy were quenched. Consequently an alloy with 9% or 10% aluminium which has been die-cast (*i.e.*, rapidly cooled), contains a much bigger proportion of $\beta$ than the same alloy which has been sand cast (*i.e.*, slowly cooled). A 10% aluminium alloy which has been foundry cast will have a tensile strength of about 25 tons per sq .in. The same alloy in its die-cast form will have a strength about 10 tons higher than this.

It is not surprising therefore that aluminium bronze has become closely linked with die-casting because its properties in this form are so extremely good, particularly for a non-ferrous

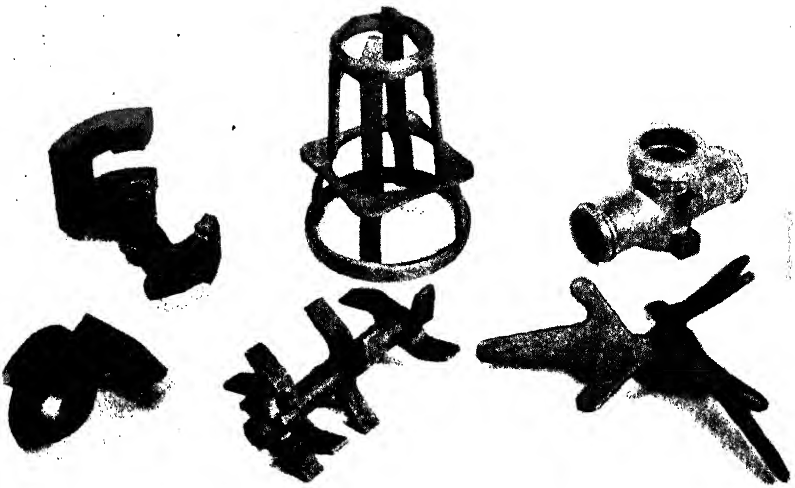
alloy. It so happens also that aluminium bronze is resistant to most corrosive agents and also it lends itself very readily to die-casting by the gravity process. Usually the 10% alloy is chosen because in its gravity die-cast form it represents the best combination of properties.

On account of the high melting point of aluminium bronze (about 1030° C. for a 10% alloy), careful attention has to be paid to the maintenance of the die. This is generally made of low carbon steel, semi-steel or nickel steel; cores are usually of some alloy steel. The life of a well made mould will be anything between 5 and 25,000 castings, depending on the size and complexity of the job. Because cores may be completely surrounded by liquid metal during casting it is frequently necessary to renew them at regular intervals, and users should watch that deliveries of these castings are closely checked in the die-caster's works so as to avoid alteration in the size of holes through the burning and distortion of core-pins.

On account of the combination of high casting temperature, brief freezing range and high contraction (the total shrinkage is over 2%), the production of satisfactory and solid aluminium-bronze die-castings requires special precautions to be taken. Abrupt changes of direction and section should be avoided; usually the section of such die-castings should be not less than $\frac{3}{32}$ in., while if it is more than $\frac{1}{2}$ in. the complete elimination of contraction cavities becomes most difficult.

Providing the die is well looked after, accuracy of plus or minus 0·005 inch per in. can be maintained. Holes of greater than $\frac{3}{16}$ diameter can be cast providing a taper of about 0·015 in. per inch is allowed on the cores, but on account of the high melting point and shrinkage of the alloy, small holes of less than this diameter should not be attempted. For similar reasons it is unwise to consider the casting of threads or the inclusion of elaborate undercuts. The weight of commercially possible aluminium-bronze die-castings ranges between 1 oz. and 14 lb.

So long as careful attention is given to the running of the die-casting, excellent results can be obtained as regards surface appearance, and the alloy in the die-cast condition has a pleasant "10-carat gold" colour. If necessary the usual finishing processes can be applied; the alloy can be nickel or chromium-plated direct and it can be coloured by heat tinting or by chemical finishing processes.



*Courtesy of Fry's Diecastings Ltd.*

**Fig. 17.—Examples of gravity die-castings in aluminium bronze, including parts for scientific instruments, bottle-washing machinery, motor-boat engines, impulse wheels, sweet-serving mechanisms, and electric fans**

Aluminium bronze is not "cheap" and therefore it cannot economically be used for the making of very simple shapes or only lightly stressed components, but where the savings in machining effected by the die-casting process are sufficient to bring the cost into line, the physical properties of aluminium bronze are an added incentive to its application. Fig. 17 shows six aluminium-bronze gravity die-castings as applied to the manufacture of scientific instruments, bottle-washing machinery, motor boat engines, impulse wheels, sweet-serving mechanisms and electric fans. Each of these quite complicated parts represents an article where the use of a die-casting brought about a considerable saving in expense.

Usually the properties of the straight aluminium-bronze alloy will be found sufficient for most purposes, but if an increase of tensile strength is desired, iron between ½% and 2% may be

included, accompanied by a corresponding drop in the aluminium content. In some cases additions of manganese or nickel may be made.

It is not always realised that, on account of the conditions described at the beginning of this article, aluminium bronze is susceptible to heat treatment and the results obtainable are nearly as remarkable as those witnessed in the treatment of steel. For instance, if exceptional hardness and strength are required, the die-casting in 10% alloy may be reheated to 850° C., quenched in water and subsequently tempered at 300° C. Another very useful treatment may be applied if it is desired to perform rapid machining operations on the alloy; in this case a softening treatment may be given by heating the bronze to between 700° and 750° C., maintaining this temperature for about two hours (taking precautions not to exceed 800° C.), the die-castings are then cooled slowly down to 400° C. and subsequently air cooled.

## CHAPTER IX

# Designing for Die-casting

IN nine cases out of ten the reason why manufacturers adopt die-castings into their schemes of production is because they will save money by so doing. But there is still a number of users who have not fully realised the economies they could make if their die-castings were designed to bring forth the maximum advantages of the process. Problems always take time to solve and if a user puts difficulties into the making of his die-castings he must expect to pay accordingly. Most die-casting firms consist of a medium-sized but elaborately equipped toolroom, with workmen who are highly skilled, and a much larger foundry with semi-skilled operators and lower overhead costs. Consequently any design which continually keeps the die in the toolroom for repairs is going to be an unduly expensive proposition.

There are two kinds of users: one is the sort who says "I am requiring some brass parts which I buy in 5-gross lots at a time, so will you quote for 5-gross brass die-castings exactly to my present design. I cannot give you an order for more because I am not sure whether I shall go on using the part. I will not consider any other metal—it would upset my arrangements. Now you quote me and let me have your price by return."

The other type of user says, "Here is a job which I would like you to die-cast. I have been buying the part at the rate of 5 gross per month for the last two or three years, and so far as I can see you could safely work out your price based on 60 gross for delivery spread over 12 months. I shall want the central $\frac{3}{4}$-in. hole to be accurate and the four fixing holes are also important. Except for these points there is nothing very particular about the design of the part and I should welcome any suggestions for modifications which would help you to

make a better die-casting. You can recommend any alloy you think suitable provided it is reasonably strong and the cost is as low as possible."

## Decisive Planning Needed

Fortunately the second class is in the majority, and the really successful users of die-castings are those who put their cards on the table at the commencement of their plans for the manufacture of a new kind of article. They realise that if the die-caster is going to suggest design modifications it is far better that these ideas are put forward in the early stages of design. To one who has not been accustomed to the application of die-castings it sometimes seem strange, even presumptuous, that the die-caster so frequently offers suggestions for the simplification of design, but it pays!

There are two reasons why the user should co-operate with his die-caster in designing parts to make them suitable for production. A component which is planned for die-casting will have a rate of output greater than that of a part which presents difficulties. The production speed of two equal-sized components may differ by 300% or more if one part is simple and the other involves difficult core movements and undercuts. Secondly, a well-designed die-casting will have a longer "die-life" than one which introduces problems. There have been many zinc-base alloy pressure die-castings which have only had a die-life of 10,000 in spite of the fact that the tools for these parts have been really well made and heat-treated before use, but there have been other more straightforward die-castings in the same alloy which have been produced satisfactorily for well over a million shots.

In designing for die-casting the user should continually bear in mind that the mould and cores are made of solid steel. The die must be closed together for the casting operation and opened prior to the removal of the finished job. Cores must be inserted and extracted; the cheapest and quickest way of doing this is by pulling them in straight lines and by grouping the core movements in as few directions as possible. A core which has to be screwed out, knocked out, rocked out or dismantled piece by piece will add considerably to the cost of manufacture.

Any design feature which hinders the rapid operation of the die should be seriously considered to ascertain if it can be amended. For instance, if a box-shaped article were to be produced having the top side open and a boss projecting inter-

nally from one of the vertical walls, then the presence of that boss would interfere with the straight line withdrawal of the central core. If the boss were either carried down to the base or transferred to the exterior it will be seen that the difficulty would be obviated. To take another example, a die-casting shaped like a bottle would present almost insuperable difficulties because the core forming the interior could not be withdrawn through the neck after the casting had solidified.

## Technical Points

Other considerations involve the selection of the best place for the runner and the parting line, and these factors affect the design because, for instance, it would not be wise to have a long slender hole situated near the runner, and accuracy would be lost if an important dimension were intersected by the

TABLE IV

***Questions to be settled from the Original Design–***

- Shall the part be produced by gravity or pressure die-casting? What alloy shall be used? Can the part be grouped into a multiple tool?
- Where will the die parting be?
- Do any holes or recesses cause the part to be undercut? Do any bosses or lettering, etc., prevent the die from opening freely?
- Will the running of the casting interfere with important cored holes? Taper on cored holes? Can cored holes be grouped into fewer directions? Is the diameter of cored holes suitable?
- Is the section correct in order to obtain good surface appearance? Is the section as uniform as possible? Will sharp corners have to be radiused?
- Are threads required to be cast? Are inserts to be included? Is special engraving or lettering required?
- Will the die-castings have to be machined? Is any special finish to be applied? Will packing include any special problem?

***–to the finished die-casting***

parting of the die. Table IV indicates a fairly logical sequence of considerations commencing with first principles and concluding with a few special factors which sometimes have to be remembered when the design of a new die-casting is discussed. Some aspects of design will be discussed in detail in subsequent pages.

Before deciding on the design of a particular component the user should visualise the whole assembly embodying the die-casting and ask himself if there is any better way of starting afresh so as to use one die-casting where two or three components were previously essential. For instance, two items which were riveted or soldered together might be united into a single die-casting. On the other hand the opposite procedure might have to be adopted; for instance, to return to the bottle die-casting which has been discussed above, the easy way to achieve such a design would be to divide it into two pieces, the circular base and the remainder of the bottle. The bottle portion could then be achieved by withdrawing the core through the maximum diameter, and the base could subsequently be attached to it, possibly by casting a male thread on the circular base and by casting or cutting a female thread at the open end of the larger die-casting.

Having decided these points, the user should also bear in mind that the part might be grouped into a multiple die with other items of the same assembly. Very often it would not pay to die-cast a small component on its own, but if it could be produced in a set with other items which work with it, quite surprising economies might be affected. For instance, it is a usual procedure in the die-casting of locks to make the case and the various working parts in the same multiple tool. Naturally, if a multiple die has to be made, the design of each part must be considered in relation to the other members of the set. To take an extreme example, it would not be possible to produce two carburettor bodies from the same die because in these complicated die-castings core movements are required in four or more directions, and the placing side by side of the two castings means that core movements would be impossible on to the adjacent faces.

To sum up, it is to the user's definite advantage to consult his die-caster at early stages of design. If the user is a large purchaser of die-castings it will pay him to make himself very familiar with the "why and wherefore" of die-casting. An excellent way of doing this is by asking the die-caster to state his reasons for any design change which is suggested.

CHAPTER X

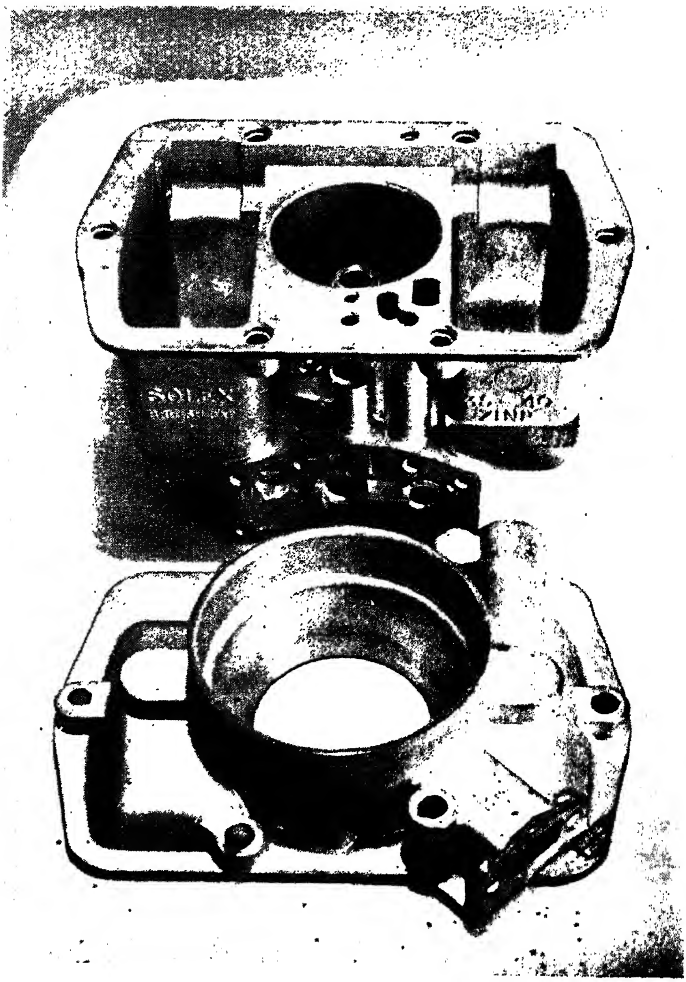
# Cored Holes

EVERY recess in a die-casting is cored by a piece of steel of appropriate shape which projects into the die cavity while the alloy is entering, and is withdrawn when the casting has solidified. There are two methods by which a cored hole may be produced. If the direction of the hole is parallel with the die movement, the core is generally included as part of one of the die-blocks, so that when the mould is opened the core is withdrawn from the finished casting. If the hole is in any other direction it is necessary to operate the core by a separate mechanism, and usually such a core would have to be withdrawn before the die could be opened.

One of the many useful features about the die-casting process is that once the die has been made, recesses of irregular shape are as easy to obtain as circular holes. It will be appreciated that if irregular holes had to be machined in every casting, the manufacturing cost might be high, for a hexagonal or splined hole cannot be cut with the same facility as a circular one. A well-known instance is where a hexagonal form is required at the bottom of a blind hole; such a feature would be most difficult to machine in the solid metal, but it could be achieved with ease by coring it in die-casting.

If the design of the die-casting is planned in accordance with the requirements of the process, practically all holes greater than $\frac{3}{16}$ in. diameter, and many small ones too, may be accurately cast. From the die-caster's point of view it is indeed preferable to core as many holes as possible, for this has the effect of breaking up heavy sections which, if solid, might be a cause of porosity. The minimum-sized hole which may be die-cast depends partly upon the alloy and partly on the design of the job. As a general rule it may be said that the lower the

melting-point of the alloy the smaller the size of hole which is possible. Thus, in a tin-base alloy (melting-point about 200° C.) holes as small as $\frac{1}{32}$ in. diameter may be cast. On the other hand, it is not recommended to core holes of less than $\frac{3}{16}$ in.




*Courtesy of Solex, Limited*

**Fig. 18.—Carburettor body and cover, pressure die-cast in zinc-base alloy. The die-castings contain over 50 accurately cored holes**

diameter in brass die-castings (melting-point about 920° C.). A further consideration is the die-casting process which is employed; usually it may be reckoned that the pressure process permits the inclusion of smaller holes than are possible in a gravity die-casting.

The design of a part affects the coring of holes in many ways. If a hole is situated near the position of the runner and at right angles to the direction of the incoming metal, it will be liable to give trouble because the continued impact of hot metal at high velocity will be bound to cause deterioration to the core. Then, because the core pin has to be pulled out of metal which has only just solidified, and is therefore comparatively weak, the rigidity of the component will affect the feasibility of coring small holes. A sturdy die-casting would permit more accurate coring than a flimsy part, and in most cases it would be possible to die-cast smaller holes in the more rigid component.

Taper is usually allowed on all parts which are cored because the core pin must be extracted from the rapidly contracting die-casting, and if no taper were allowed the core would either stick in the casting or its forcible extraction would score the walls of the part. Very often when a long hole has to be cast, it is stepped, so that when the core has been withdrawn through a part of its length the narrower end passes through the increased diameter and will not touch the die-casting during the remainder of its extraction.

It is difficult—almost impossible—to give recommendations about taper which must be allowed on cored holes. Every job should be considered on its merits, and the user should allow his die-caster to decide what tapers are necessary. However, table V may be a rough guide about the approximate taper to be allowed on cored holes.

TABLE V

APPROXIMATE TAPER TO BE ALLOWED ON CORED HOLES.

| Alloy | Taper per Inch of Length: In a flimsy Die-casting | | In a sturdy Die-casting | |
|---|---|---|---|---|
| | Long slender hole | Short hole | Long slender hole | Short hole |
| | Inches | Inches | Inches | Inches |
| Tin and Lead Base | 0·0005 | Nil | 0·0005 | Nil |
| Zinc Base (pressure) | 0·003 | 0·002 | 0·002 | 0·001 |
| Aluminium do. ... | 0·025 | 0·02 | 0·02 | 0·015 |
| Brass ... do. ... | Do not attempt | 0·025 | Do not attempt | 0·02 |
| Aluminium Bronze (Gravity Die-cast) | Do not attempt | 0·030 | Do not attempt | 0·025 |

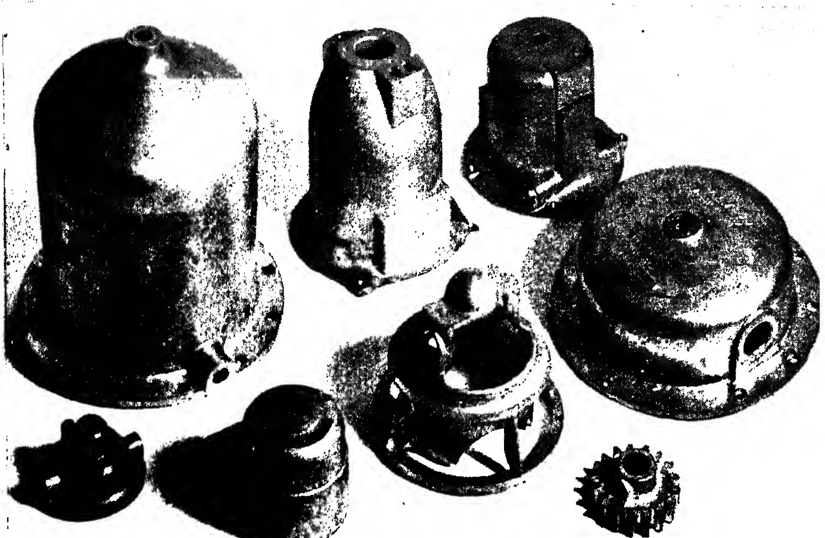
Long, thin holes with insufficient taper will distort because the continual pulling of the core pin under constraint will set up unequal stresses. You can demonstrate this effect by pulling a hair between two finger nails; the hair will curl, and this, to a lesser extent, is what happens to an insufficiently tapered core pin. If troubles like this do crop up, considerable delay is likely to occur; for instance, if the core pin sticks when the die is closed, it is sometimes impossible to open the die at all without smashing the core.

The accuracy of a cored hole depends on the skill with which the die has been cut and heat-treated, on the rigidity with which the core pin is supported in the die, and on the maintenance of the core when it is in use. Modern machine tools such as the jig borers have considerably helped in the more accurate location of cored holes, but it is the design of the casting and the controlled operation of the die which decide whether an accurately cut tool shall continue to produce accurate die-castings.

Accuracy is easier to maintain when the core is included as part of the die-block, for the rigidity of the mould makes it practically certain that the core will not be displaced when the metal is injected. In pressure die-casting in particular the impact of the injected metal is so great that a real problem arises of locking cores securely in position during casting but ensuring that the locking device is capable of rapid unlocking as soon as the casting has been made. If a core is contained as part of the moving die-block, the hydraulic or other forces which hold the die together will also keep the cores accurately in position. It will be appreciated that a design which involves a multitude of core movements will be more liable to inaccuracy than a part which is cored in the minimum of directions.

Cored holes, therefore, should be designed to lie in as few directions as possible, and in many cases they may be arranged solely in the direction of the main die movement. If you look at an electric motor body which has been die-cast you will in most cases observe that the ventilation holes have been cored in the direction of the opening of the die, and not radially as is more usual in a non-die-cast housing. This is one of the cases where consultation with the die-caster in early stages of design has brought about modifications which are to the advantage of all concerned.

Fig. 19 shows a group of large and small pressure castings which have all been produced by running on to the top, and coring the main cavities by the moving die-block. The fixing



*Courtesy of Fry's Diecastings Ltd.*

**Fig. 19.—All these pressure castings were run at the top of the "dome-shaped" portions**

holes on the flanges of the four largest parts have, of course, been produced by separate corepins working in the moving half of the die. Shapes such as those illustrated are particularly suitable for pressure die-casting owing to the speed of operation possible when core movements are kept to so few directions.

The problem of casting blind holes occasionally introduces difficulties. If a hole is blind, the core making it will be supported in the die at one end only, while if possible a core making an open-ended hole is held at both ends during casting. Particularly in pressure die-casting, each injection of metal will tend to displace and bend the core pin. The effect is not serious if the hole is short, but if, for instance, the hole were 4 in. long and ¼ in. diameter, the core which was only supported at one end would be so flexible that it would be displaced after every few casts. In such cases it is preferable to cast the hole open-ended, and it is quite a usual and convenient practice to plug the end of such a hole.

If possible, cored holes should not be located on the parting

line of the die, for it would be necessary to have an overhung housing to support the core. Very often, by co-operation with the die-caster, the design may be modified so that the parting line takes a different course or the position of the hole is moved.

From a consideration of the operation of cores it will be apparent that holes which cross each other introduce difficulty because they involve the problem of one core pin passing through another. In special cases this procedure may be carried out, providing that the one core is at least twice the diameter of the core which penetrates it, and of course the smaller core must be withdrawn first. When crossing cores are used the likelihood of die breakdown is definitely increased, for a displaced core which was not noticed might bring about jamming of the die. In many cases where crossing holes are essential it is better to core the larger hole and cast the smaller one for part of its length only, so that the penetration of cores is not necessary. The remainder of the smaller hole can then be drilled, locating from the part of it which has been cored.

CHAPTER XI

# Undercuts

WHEN a die-casting is designed in such a way that a recessed feature interferes with the straight line withdrawal of cores or the opening and closing of the die, it is said to be undercut. Figs. 20-22 illustrate several types of undercut die-castings which are regularly being produced. The problem is of special importance to the user, because the permanence and rigidity of the steel mould make certain designs difficult (and sometimes impossible) to execute.

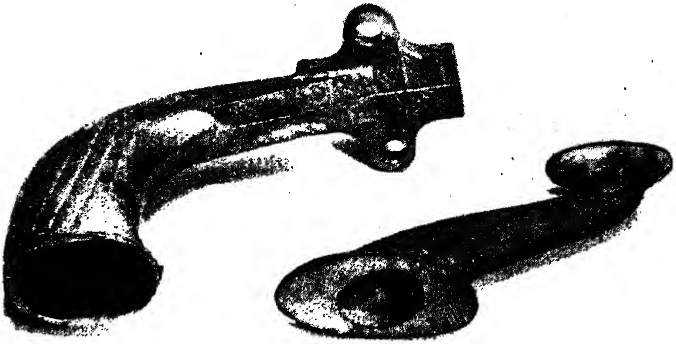


**Fig. 20.—Undercut die-castings. Holes formed by rotating cores**

In the operation of the ordinary foundry this problem does not so much arise, because after every cast the sand mould is collapsed; thus, for instance, a bottle could be sand cast but, as already pointed out on page 59, the inside portion could not be cored commercially in a die-casting.

The production of undercuts involves the manipulation or the dismantling of the core, and consequently it must be expected that an undercut part will take longer to produce than a straightforward one. In particular it is difficult to manipulate cores in the pressure die-casting process because the necessity of locking the parts of the die during casting makes it correspondingly difficult to release and withdraw such cores in a curved or zig-zag path. Gravity die-casting, being a manually operated process, lends itself more to the making of undercut designs, and the hundreds of thousands of automobile pistons which are gravity cast bear witness to the adaptability of this process to the making of complicated undercut patterns.

There is a number of standard ways for producing undercuts which will now be described. If a hole is curved so that it forms the arc of a circle it is possible to core such a hole by rotating the core about an axis. Fig. 20 shows two die-castings which have been cored in this way; the hole which passes through the smaller component was, of course, made by two cores which met at the centre. In each case the positive withdrawal of the core was effected by means of a curved rack. Readers will have seen domestic taps which have been pressure die-cast in brass, and it may have been noticed that the outlet portion was curved in a quarter circle to allow the withdrawal of the appropriate core which formed this hole (incidentally, in this country it has been found that domestic taps are not a really commercial possibility produced as brass pressure cast-

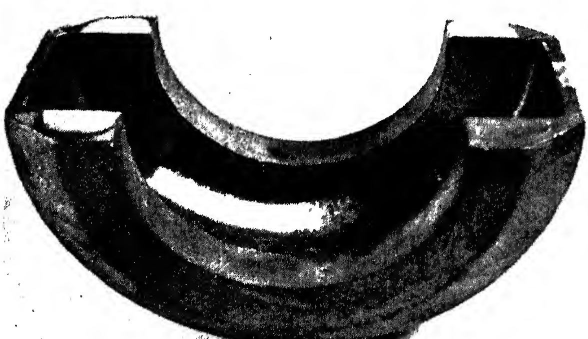


**Fig. 21.—Recess formed by a collapsing core**

ings; there is still too high a percentage of scrap brought about by porosity troubles).

In some special cases a hole which is other than circular may be cast; for instance, a quarter ellipse could be cast, providing the core was tapered and curved in such a manner that it would not come into contact with the die-casting during its removal. Certain tone arms for gramophones have been die-cast in this way, using an arrangement of cams for actuating the core.

In gravity die-casting the method of "collapsing" cores is frequently used; by this method the recess is cored by several loose pieces, one of which is straight. The straight piece is arranged to be withdrawn first, and this allows the other parts of the core to be collapsed inwards. Fig. 21 shows a gravity die-casting in aluminium alloy which has been made in this way. The central core piece was rectangular while the outside pieces were L-shaped (the L-portion forming the undercut recess, which will be clearly seen). After the central piece has been extracted, first one and then the other side cores could be directed towards the centre and withdrawn through the cavity formed by the removal of the first piece.

Arising out of this example it will be seen that if the length of the base of one of the L-shaped portions were greater than the width of the central core piece, the undercut would not be practicable because the L-core piece could not be extracted through the central cavity.

Quite a similar method exists for the production of undercut pressure die-castings, but on account of the force of injection of the metal it is necessary to lock the built-up cores securely together, and usually such cores are dismantled by a separate operator after the casting has been extracted from the die. Fig. 22 shows a typical example. It will be seen from the marks on the die-casting that a wedge-shaped core piece has been pulled through the hole on the left. This takes place while the casting is still in the die. After this core has been withdrawn the die is opened and a three-piece core remains locked together forming the remaining two-thirds of the undercut recess; incidentally, during the casting operation this "knock-out" core was secured by locating it on the part of the die which forms the circular hole visible in the base of the casting. After the casting has been taken from the machine with the knock-out core still included, another operator unlocks the core, pulling first the rectangular portion away, and then lifting the two side pieces out.

**Fig. 22.—Undercut die-casting in which one core was extracted through the hole seen at the left of the casting, and remainder of main core was "collapsed" subsequently**

It is necessary to have three sets of knock-out cores, so that while the assistant is dismantling one set, a second knock-out is in use on the machine and a third is ready for the next cast. Because a second operator is necessary, and because of the slower output caused by the positioning of the knock-out, the cost of producing the part was greater by at least 30% than that of making a straightforward pressure die-casting.

For the making of very difficult undercuts there is one method which can be employed as a last resort, but it is definitely not a favourite. A circular part such as that which

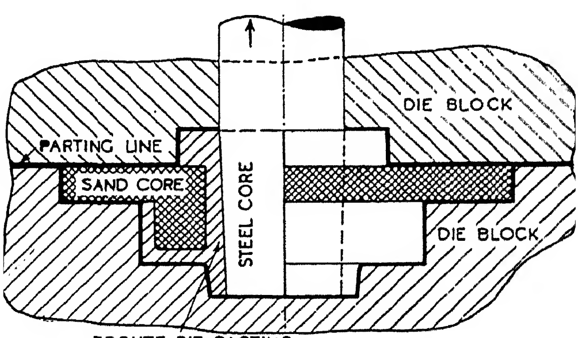



**Fig. 23.—Arrangement of combined sand and die-casting**

is illustrated in Fig. 23 might be made to include a sand core which would form the recess between the trough portion and the ledge around the central diameter. The sand core is used

just as though a foundry casting were being produced. However, the combination of sand and die-casting is extremely messy and should be avoided if possible. In any case, it should only be applied to the making of gravity die-castings, as the presence of sand cores with a complicated piece of mechanism like a pressure die-casting machine is too dangerous to make the practice anything but a curiosity.

Primarily for the reason that undercuts mean added cost, it pays to examine the design of a part to see if undercuts can be obviated. Sometimes it is better to die-cast the component without the undercut and to machine the recess or hole by a subsequent operation. But the best method is to consider the part afresh and decide whether it is possible to make the part a more straightforward job by designing it in a different way.

CHAPTER XII

# Factors Relating to Die Opening

A DIE-CASTING mould is usually made in two parts which are closed togther for the entry of the metal and opened prior to the removal of the solidified casting. Consequently, the parting line must be arranged so that the die can be conveniently opened and closed; for instance, if a sphere were die-cast, the only possible die-parting would be around a major circle. If a part like a cotton reel were to be produced, it would not be sensible to cast it so that the parting line was parallel with the flat ends, because the rims around these ends would prevent the die from being opened once the casting had solidified. The reasonable way of producing this part would be to have the parting line longitudinal so that a half cylinder would be sunk in each die-block. Arising out of the fact that the mould is rigid and that it must be opened and closed as rapidly as possible, quite a number of conclusions may be drawn.

### (1) *The part should be arranged to leave with the moving die-block*

Particularly in pressure die-casting it is important that the part is designed in such a manner that when the mould is opened the die-casting will regularly be drawn away with one selected half of the die. For convenience this is generally the moving die-block. This is because a pressure die-casting has to be ejected from one die face, and in most cases it is more practicable to arrange the ejector mechanism on the moving die-block rather than in the half of the mould from which the metal is cast.

Users would be well advised to agree with their die-casters' suggestions if ever it is recommended that a small alteration is necessary to compel the die-casting to come away with the moving die-block. A typical modification which might be requested is the addition of flats inside a dome or cone-shaped

recess. These flats grip the moving die-block when the casting contracts and allows the die-casting to be withdrawn in the required direction. If the design were such that there was no feature to grip the moving die-block, the die-casting might adhere to the fixed block, with the runner still embedded in the sprue; as there would be no ejectors on this side it would be difficult to extract the casting.

As always, every endeavour should be made to facilitate the rapid operation which can be achieved in the die-casting process. The above remarks do not so much apply to gravity die-casting because here the mould is operated by hand, production speed is expected to be slower, and the die is usually more "get-at-able" than a pressure tool.

*(2) When possible the parting line should be straight*

It is important that the two die-blocks fit closely together, otherwise liquid metal may escape during the casting operation; grinding is the best method of ensuring this close fit, but the

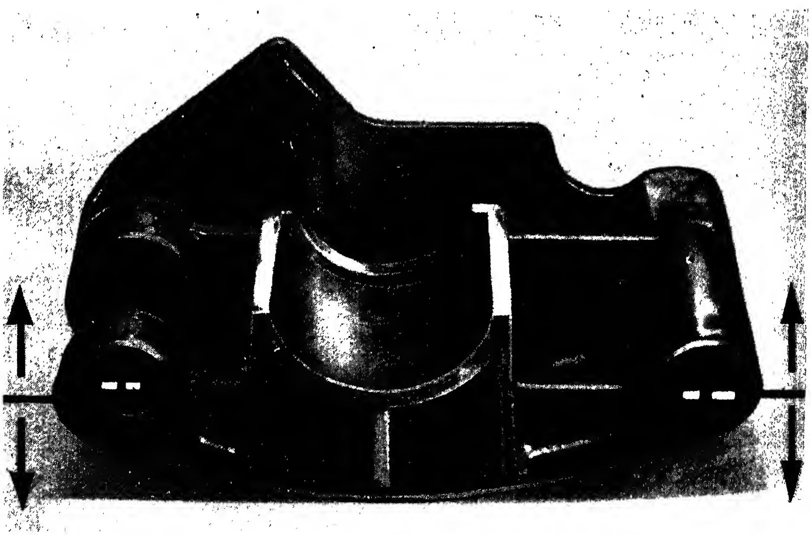


**Fig. 24.—Alluminium alloy pressure die-casting indicating parting line**

die-blocks can only be ground if the parting line is straight. With an irregular parting line it becomes necessary to machine the die face, and a good fit is more difficult to obtain under such conditions.

It will be apparent that if the die parting is flat and at right angles to the line of die opening, the accuracy of the product will be greater than it would be if the parting were inclined at an angle. For instance, if the parting plane were at an angle of 45°, every injection of metal would cause an additional side thrust on to the tool, and at every cast there would be a shudder in the die. The writer remembers cases where die-castings with irregular parting lines have developed cracks due to this side thrust on the tool.

In these days such complicated parts are being die-cast that very often it is impossible to arrange for a straight parting plane. Fig. 24 illustrates an aluminium alloy pressure die-casting embodying an irregular parting line which is indicated on the photograph. The die moves in the direction shown by the arrows, the recesses in this direction are cored by the moving die-block, from which the casting is ejected. The two side recesses beneath the bearing housing are cored by a separate movement.

### (3) *The parting line provides the principal method of venting*

Before the metal is introduced the die is full of air, which must be completely displaced before the incoming metal. If the air cannot be dispersed there will be a likelihood of porosity where it has become entrapped in the solidifying alloy, and secondly there will be a loss of accuracy because the air will have a cushioning effect and the metal will be unable to fill sharp corners completely. Consequently, the die must be vented in such a way that air can escape, but the vents must be so narrow that metal will not escape through them.

The procedure varies somewhat in the gravity and pressure processes, and in particular the former allows the use of wider vents. In the pressure process any vent wider than 0·003 in. makes it possible for liquid metal to be forced through the vent channels.

In many cases the die parting is sufficient to vent the casting adequately. Also if any cored holes are present, the clearance between the core pins and the die will be an additional method of venting. In the gravity process, where a large stepped cored hole is included it is often necessary to use telescopic

cores with flutes cut into them in order to allow the ready removal of air through the spaces of this composite core. Particularly for an irregular shaped or a large die-casting it is necessary to provide vent channels which are depressed into the parting plane at suitable positions. In some cases a vent has to be provided all the way round the die-casting.

On occasion it is necessary to vent at a position other than the parting line. If the die were cut in the solid, such a procedure would be difficult, and in this instance it becomes necessary to build up the die-block in two or more pieces which are afterwards carefully fitted together. The mere fact that there is discontinuity between these sub-assemblies may be sufficient to vent the die-casting at any desired point. This procedure is more frequently met with in the gravity process, because in pressure die-casting the splitting up of a die-block means reduced length of service.

Skilful venting is one of the things which makes die-casting so much an art. It is mainly a matter of inspiration coupled with long experience, but the satisfactory venting of a die makes all the difference between a porous, seamy casting and a solid, accurate job. Usually the die is tested before any additional venting is added. The appearance of the first few samples will exhibit flow lines and regions of porosity which, to the skilled die designer, will tell how the mould must be vented to clear away these indications of metal eddies and air locks. Sometimes a die has to go backwards and forwards to the toolroom three or four times before the die-casting is considered perfect.

### (4) *The die parting determines the possibility of coring from the moving die-block*

On page 65 it was stressed that accuracy is much easier to obtain if important holes are cored from one of the die-blocks. When confronted with a new design the die-caster usually decides whether it will be possible to arrange the parting line in such a way that important holes may be cored from the moving die. For instance, in the motor body shown at the right of Fig. 25 the casting was run at the top of the domed portion; the central cavity which can be seen in the picture was cored by the moving die-block, and the parting line was around the rim. The ejector pin marks will be clearly seen near this edge.

On the other hand, the vacuum cleaner body on the left of the illustration was not so convenient for casting in this manner.

It was run at the oval hole which will be seen in the lower portion; the moving die-block cored the circular recess which is shown at the top of the picture. The large double chamber was cored by a separate moving member entering at right angles to the direction of running, and the parting line was irregular. The fan on the same illustration was cast on to the central hole, the blades were cut into the moving die-block, and the parting line was around the rim.

(5) *There will be a flash at the parting line*

The die-casting, when it leaves the mould, will be accompanied by a thin flash where the two halves of the die are joined together. In addition, the runner will be adhering to the casting, and there may be a flash at the positions of the ejector pins and movable cores. All these have to be trimmed by a

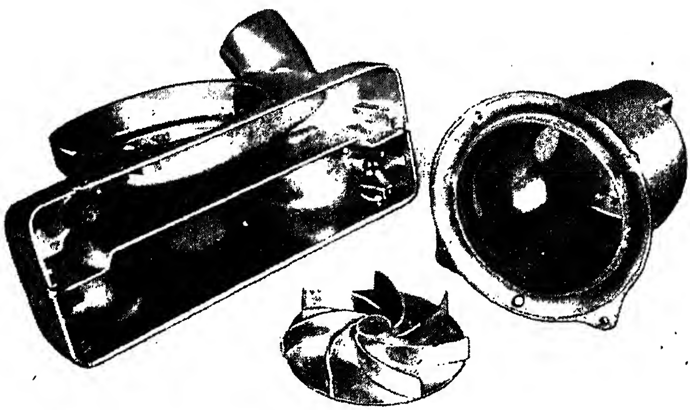


**Fig. 25.—Vacuum cleaner parts pressure die-cast in aluminium alloy**

separate operation, and, indeed, the removal of fins may account for a substantial proportion of the cost of the die-casting. By careful attention to design the part can be planned so that a minimum amount of trimming will be necessary, but it must be admitted that most of the responsibility lies with the die-maker. A badly made or worn-out die will give rise to many more trimming problems than a carefully made tool.

The chief way in which this problem will affect the user is that he may occasionally be asked to agree to a small alteration: for instance, so that the parting line can be arranged at a sharp edge on the casting in order to locate the flash in a position where it can be easily removed without leaving an unsightly mark on the component.

(6) *The parting line position effects the accuracy of the die-casting*

If any special dimension should be required to maintain a very close degree of accuracy, such a locality should not be crossed by the parting line. Every time the liquid alloy is introduced into the mould there is a tendency for the die to open, and consequently a dimension which is intersected by a moving die member cannot be expected to maintain such a high degree of accuracy as a part which is included by a solid block. This is one of the reasons why the designer should indicate on his print any dimensions which are of special importance.

CHAPTER XIII

# Inserts

SOMETIMES a die-casting is required to display a combination of properties which no one material could be expected to possess. Perhaps the intricacy of the zinc-alloy product or the lightness of aluminium is wanted side by side with the hardness of steel or the qualities peculiar to a bronze bearing. Thus a motor-car door handle would have a steel shank and a zinc-base alloy body; an electric motor casing might have a bronze bush to act as a bearing if the stresses were considered to be too high for the unsupported die-casting.

There is practically no limit to the range of substances which can be included as part of a die-casting. Brass and steel are the most usual insert materials, but fibre, plastics, compressed paper, soft iron and other die-castings have all been used with success.

In designing a die-casting which is to include an insert, one should try to picture the procedure in the die-casting operation. The insert must be securely located in the die in such a way that when the metal is cast it will flow around the insert, gripping it firmly so that it will become part of the die-casting. It will be apparent that the insert must be so positioned in the die that it will be accurately located in the finished casting; secondly, it must be held in the die so that it will not be displaced by the incoming metal. At the same time the method of fixing the insert must not interfere with the easy removal of the finished article; this is bound up with the third consideration—that of the need for accuracy of the insert itself.

That part of the insert which is to be gripped by the die for the purpose of location, but which is not required to be covered by the die-cast metal, should be of a high degree of accuracy, otherwise liquid metal will penetrate into the gap, causing the tool to lock. For instance, if a brass bush were required to be

cast in to act as a bearing, it might be located by a central core, in which case the internal diameter of the bush must be accurate to within plus or minus 0·001 in. per inch. Should the fit of the insert be sloppy, liquid metal would be forced between the core and the bush so that if an attempt were made to eject the casting from the mould the core pin would probably be scored or even jammed.

It is usual to specify that such inserts shall be maintained to the limit of accuracy given above, but it will be realised that the dimensions of the part of the insert which is embedded need not be to such fine limits. In any case, however, it is desirable that this portion which is covered by the die-cast alloy should be reasonably accurate, otherwise the running of the die-casting as visualised by the designer will be interfered with.

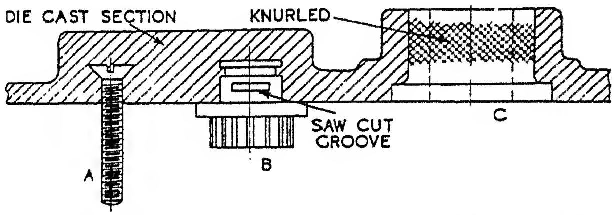
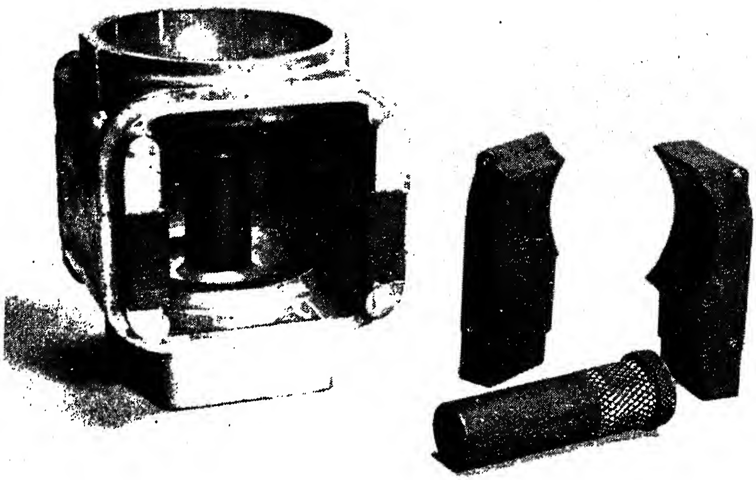



**Fig. 26.—Suitable forms of inserts regularly used in die-castings. A: Countersunk screw. B: Shouldered gear form. C: Flanged bush**

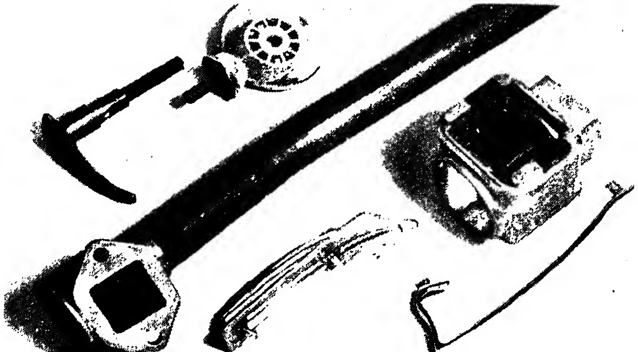
The insert must be prepared in some way so that the die-cast metal will anchor firmly to it. If a plain brass bush were " cast in " the insert would be liable to work loose after it had been in use for some time. If a groove were turned on the circumference of the insert, the ridge of die-cast metal would prevent the extraction of the bush, although rough usage would probably cause it to rotate.

For 100% effectiveness the insert must be machined in such a manner that it will be prevented from moving in *any* direction. A knurled finish is very suitable for ensuring the complete anchorage of an insert. If a threaded peg is required to project from the die-casting, ordinary commercial grub screws or countersunk headed screws are convenient to use as they embody slotted heads which are embedded in the die-casting and prevent the insert from becoming loose should the nut be repeatedly over-tightened. Fig. 26 illustrates suitable forms of inserts which are regularly included in die-castings.



*Courtesy of Wico Ltd.*

**Fig. 27.—Die-cast magneto body incorporating inserts**



*Courtesy of Fry's Diecastings Ltd.*

**Fig. 28.—Group of pressure die-castings with inserts**

Fig. 27 shows quite a complicated aluminium silicon alloy pressure die-casting which has been produced with the inclusion of inserts. The casting is a magneto housing in which the rotor bearing stud is formed from a steel tube, knurled at one end where it is gripped by the die-cast metal. The pole pieces are built from soft iron laminations which are securely fastened together so that the metal does not penetrate between them during the casting operation.

It may be interesting to record that the rotor which forms the armature of this magneto was produced in a similar way. Pure aluminium was pressure-cast round the laminations under a pressure of over 3 tons per sq. in. on a hydraulic die-casting machine. The electrical requirements of the item demand the use of pure aluminium for this part and it has been found that the "backing up" effect of the iron plates coupled with the

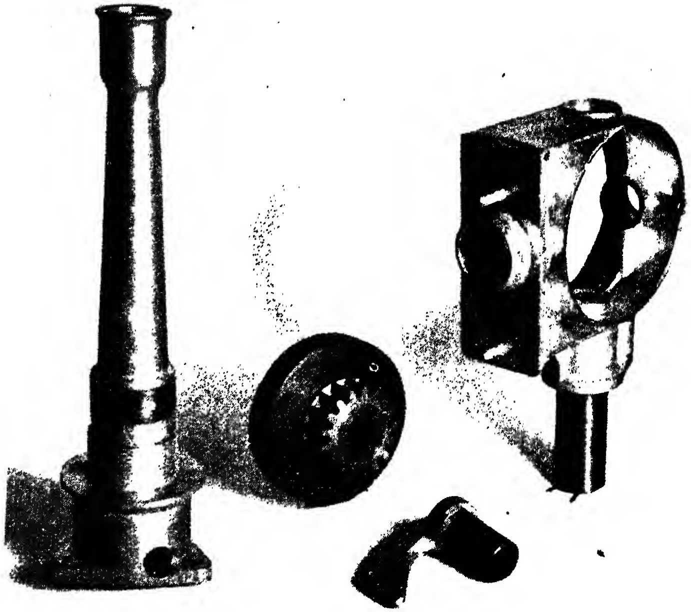
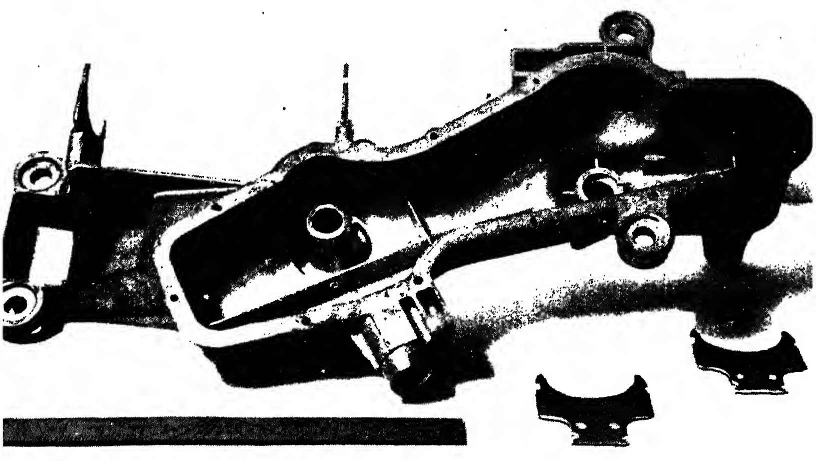


**Fig. 29.—Group of pressure die-castings including inserts**

high feeding pressure prevents the cracking of the die-cast metal during its solidification and shrinkage.

Fig. 28 shows a miscellaneous group of pressure castings, including inserts. In particular the one at the centre is interesting because the steel tube insert is so very much larger than the die-casting. Fig. 29 is another group. The gearwheel at the centre is interesting because the "insert" (the cast-iron exterior) is much larger than the die-casting (the central gear portion). Fig. 30 shows a zinc alloy pressure casting accompanied by the inserts which have been used. The casting weighs 14 lb.

Whenever a designer contemplates the inclusion of an insert in any die-casting he should always consult the die-caster who is to do the work before finally settling on the design. An



*Courtesy of Hotpoint Electric Appliance Co. Ltd.*

**Fig. 30.—Washing machine gear case showing two steel inserts which are included**

insert which is to be located in an unsuitable position (*e.g.*, near the runner and at right-angles to the flow of the metal) is liable to cause difficulty in the operation of the die and will be an ever-present likelihood of damage.

It must be remembered that the casting in of an insert is

bound to add to the cost of production. Although the die operators develop a surprising skill in positioning the inserts into the tool, this operation does take time, especially as the die will be hot, and the insert frequently has to be pressed into a part of the mould which the workman cannot even see. The writer calls to mind a zinc-base alloy pressure casting which was in the form of a long narrow strip about 36 in. long. It was subsequently decided to "cast in" seven brass pins into the strip to improve the method of fixing, which previously had to be done by riveting. When the seven inserts were included in the die-casting the production speed was exactly halved.

In all cases provision must be made for scrap loss. If the insert is medium sized there should be a supply available of about 5% above the number of die-castings to be produced. If the insert is very small an allowance of 10% to 15% must be provided to allow for damage, scrap and loss. When the die-casting has to be delivered over a period it is preferable that the user supplies the full bulk of inserts so that the die-caster can produce for stock if it suits his organisation to do so.

CHAPTER XIV

# Choice of Section

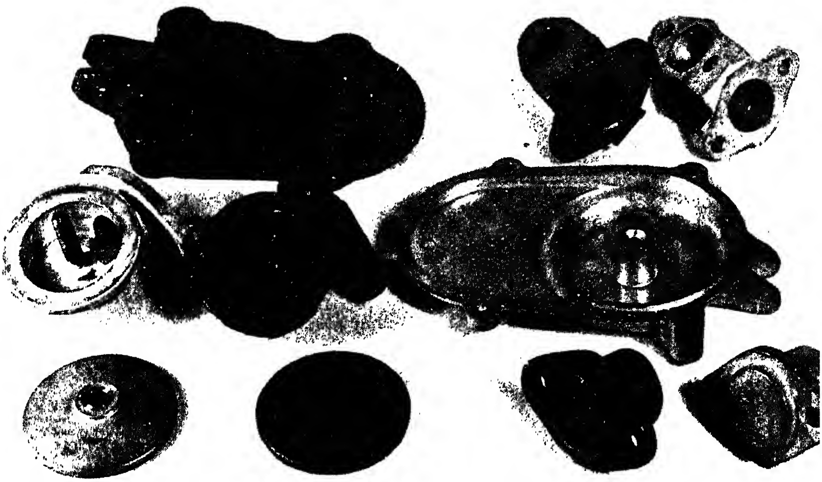


**Fig. 31.—Zinc-base alloy die-castings and the iron castings they replaced**

FIGURE 31 illustrates a group of zinc-base alloy die-castings together with the cast-iron components which they replaced. The weight of the pressure castings was almost exactly half that of the cast iron in spite of the fact that there is little difference in the specific gravity of the two metals. In this, as in most cases, the reason for the comparative thickness of the foundry casting was not the need for

heavy section due to the stress which the parts had to stand, but was owing to the fact that the foundry castings could not conveniently be run at sections less than $\frac{1}{8}$ in. This example illustrates that very often a die-casting can replace quite a simple iron casting almost solely because a reduction of section becomes practicable when the die-casting process is applied. There is a number of considerations associated with the section of die-castings, and these are listed below.

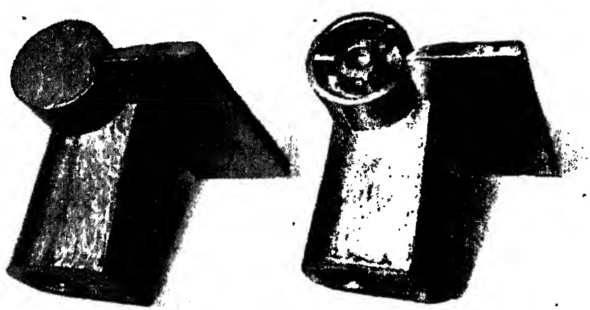


**Fig. 32.—Aluminium bronze gravity die-castings showing how the design was amended to prevent porosity**

*(1) Section influences cost*

On an average one can reckon that about half the cost of a die-casting is made up of the price of the raw material. This is naturally not a general rule, but it roughly applies to jobs of medium size. It follows, therefore, that if the section can be reduced there will be an advantage in price and, as will be seen from the other considerations discussed below, reduction of section is often to the advantage of all from a quality point of view.

*(2) Section influences the rate of cooling*

The die cannot be opened until the casting has become completely solid. In these days the die-casting process—particularly the pressure method—has advanced to such a stage that from the mechanical point of view there is almost no limit to the speed with which die-castings can be manufactured. Automatic core-operation devices, automatic ejection, and the general improvement in the mechanism of die-casting machines

have made possible a production rate of over 1000 shots per hour where the section of the die-casting makes this speed possible. But if the part is bulky and of heavy section the speed of operation will be considerably limited by the time which is taken for solidification. There are many large pressure die-castings which can only be made at the rate of 15 to 20 per hour. It follows, therefore, that not only does a reduction in section affect the cost from the obvious reason, but by increasing production speed the cost can be further lowered.

*(3) Effectiveness from a strength point of view does not entirely depend on cross sectional area*

If a bridge or an aeroplane were constructed of heavy blocks of steel they would doubtless be very strong, but the excessive weight of their own material would mean that they would be most ineffective if they were supposed to do the kind of jobs which are expected of bridges and aeroplanes. The metal in their construction should be disposed on scientific principles so that wherever there is stress there is a suitable section arranged to withstand that stress. Just the same principles should apply to the designing of die-castings. If, for instance, a plate-shaped article were required to withstand a certain amount of twisting, it would be foolish to make a bulky die-casting an inch thick. It would be sensible to cast a fairly thin plate with a rim all the way round it and webs disposed across the plate if these additional supports were necessary. Wherever a web or rim was present it should be merged into the die-casting with a suitable radius. This is important because sharp corners mean lines of weakness.

*(4) Section influences solidity*

In any die-casting the ideal which is aimed at is a uniform section with all sharp corners amply radiussed. By this means the cooling of the casting is allowed to be uniform and so we do not get troubles through one solidified part of the casting pulling on another semi-solidified portion. In a uniform die-casting whose section is $\frac{3}{16}$ in. or less, it is to-day possible to obtain complete solidity, but if localities of bulky section are present it is a matter of chance whether these thick portions will also be solid.

Fig. 32 illustrates in rather an interesting manner a case where porosity was prevented by making the section uniform. The part was an aluminium bronze gravity die-casting for a door fitting. Originally the casting was produced as the illustration on the

left-hand side. A hole had to be drilled through the centre of the flat end of the barrel, but owing to the local heavy section it was found to be impossible to prevent contraction cavities. Subsequently the die was altered so as to relieve the base as shown in the right-hand illustration, and because by so doing the section was made uniform, the contraction cavities were completely eliminated. It should always be attempted to make the section uniform, but the higher the melting-point of the alloy the greater becomes the necessity of achieving this. Very often an evening-up of section prevents local distortion which can take place in die-castings whose section is irregular.

(5) *Section influences surface appearance*

Particularly in pressure die-casting it is possible to cast sections ranging from less than $\frac{1}{32}$ in. up to 1 in. or more. It seems that every job has an optimum section at which the best results are obtained as regards surface appearance. On the metal being introduced into the die and rapidly filling it there is a certain amount of surging and eddying, and if the metal becomes too turbulent this is reflected in the presence of seaminess in the finished casting. Thus, in certain very small pressure die-castings it is possible to cast a section of $\frac{1}{64}$ in., but if the part were large and this section was spread over a wide area it would not be possible to produce a satisfactory job.

For a large area either the section would have to be increased or preferably a number of ribs would have to be introduced to allow the metal easy access across the wide surface. In the die-casting of domestic door-plates it has on several occasions been found that if, in an endeavour to reduce cost by making the section too thin, the metal has not run correctly, the finishing has been more expensive than it would have been had the section been thicker.

(6) *The suitable section depends on the alloy and on the size of the die-casting*

Usually it may be reckoned that the lower the melting-point and the more fluid the alloy, the thinner the section which can be achieved. However, as mentioned above, the section also depends on the surface area. For tin, lead, and zinc-base alloys the section on ordinary jobs should not be reduced below $\frac{1}{32}$ in. For aluminium alloys in the pressure cast condition the section should be $\frac{1}{16}$ in. or more, and for gravity cast aluminium, aluminium bronze and brass the optimum section lies between $\frac{3}{32}$ in. and $\frac{3}{16}$ in.

CHAPTER XV

# The Die-casting of Threads and Gears

THE die-casting process, particularly the pressure method, makes possible the achievement of intricate thread and gear forms. Fig. 33 shows some results which have been obtained with zinc-base alloy, and Fig. 34 indicates that gear forms may be achieved with success in aluminium bronze, although it must be admitted that the high melting-point of this alloy makes the casting of threads impracticable. Naturally certain shapes are simpler to die-cast than others; for instance, bevel-gears are easy because the casting can " leave " with facility. On the other hand, a spiral formation of teeth would be practically impossible to die-cast. Similarly, Whitworth threads are easy to die-cast, but square threads are not so suitable.

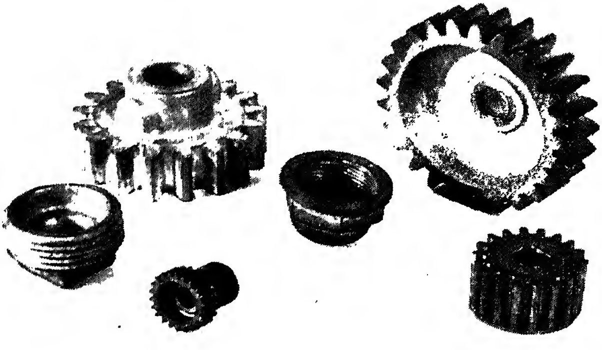


**Fig. 33.—Gears and threaded pressure die-castings in zinc-base alloy**

## Die-casting of Threads

There are four methods by which threads may be produced in a die-casting, and these are illustrated in Fig. 35.

(1) If an unbroken external thread is required it is possible to cast it accurately by including a threaded knock-out in the die; a typical result is shown on the left of the photograph. The loose piece contains a female thread of suitable size so that when the casting has contracted it will have an external thread of the desired pitch. The knock-out is fixed into the die assembly and the finished casting is extracted with the threaded block adhering to it. This is removed by a separate operator. Very often such a tool contains two or more impressions, but in any case there must be an adequate supply of loose pieces, so that production can proceed with maximum speed.

(2) Both internal and external threads can be formed by screwed core pieces which are "wound out" while the casting is still in the tool. For instance, in the perambulator wheel caps, shown second on the left, a ring of castings is made in a

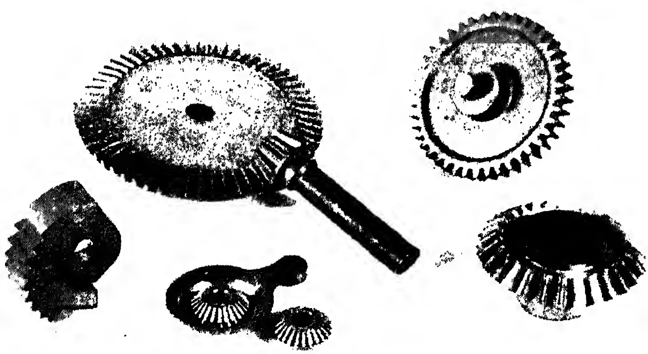


**Fig. 34.—Gear forms gravity die-cast in aluminium bronze**

multiple tool and the screwed cores are geared together about a central axis, so that when the operator turns a handle all the cores are simultaneously extracted.

For this procedure it is necessary that the external form of the die-casting is such that it will be prevented from rotating while the core is being withdrawn. Otherwise it would just turn round and round with the core piece. Thus it would not

be practicable to cast an internal thread in a cylindrical die-casting, but if flats could be arranged on the outside face the casting would be prevented from rotating in the die and the part would then be die-castable.

(3) If an external thread is required which need not be die-cast very accurately, it is convenient and considerably cheaper to part the die across the thread. The threaded impression is sunk into the tool in such a way that the parting line bisects it. In the third group in Fig. 35 it will be observed that the parting line runs across the base of the die-casting and forms a flash at right angles to the threads. Sometimes it is necessary to chase the die-cast thread which is being formed in this manner. The presence of the flash coupled with a slight loss of accuracy on account of the intersecting of the parting line, means that such a thread will not be absolutely true.

(4) The die-casting on the right tells a story with a moral. A good many years ago this pull-on switch guide was die-cast with the threads included. Subsequently a new die had to be made, and when costs were carefully analysed it was discovered

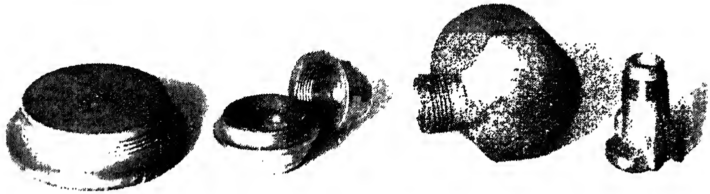


**Fig. 35.—Zinc-base alloy pressure die-castings, illustrating four methods of producing threads**

that about 1s. per gross could be saved if the part were die-cast unthreaded and the screwing were done by a subsequent operation. With improvements in modern machines, screw cutting can be carried out amazingly quickly and cheaply. It is always worth while to investigate whether the machining of fine threads, small holes, etc., will prove more economical than attempting to include these difficult details in the die-casting.

Before concluding the subject of threads there are a few points which are worth remembering. Threads should rarely be specified in aluminium and in copper alloy die-castings, for the high casting temperatures of these metals result in greatly

reduced die life when complexities such as threads are attempted. Small internal B.A. threads should not be die-cast; it is better to tap them, but the cored hole can usually be cast to tapping size. Although it is possible to die-cast threads as fine as 30 to the inch in zinc-base alloys, it is wiser, for the sake of die life, not to attempt to cast threads finer than 20 to the inch.

Users are beginning to appreciate that there are many advantages to be obtained by the die-casting of threads. For instance, threads can be started "full" (*i.e.*, without the usual sharp feather-edge), and carried right up to a shoulder, whereas it is very difficult to machine such forms. Again, taper threads can be produced, and also two different diameters of thread can be cast by the same core so long as the pitch remains constant.

## Die-casting of Gear Forms

The accuracy with which gears can be die-cast has led to a wide application of the process to this kind of work, and the results of pressure die-casting have proved of special value. Providing the design is such that the tooth form is able to clear the die, gears can be cast to an accuracy equal to a fully machined (but not ground) gear. The strength of such die-castings approaches that of steel, and in recent years many users have been surprised at the strength and reliability of pressure die-cast zinc-base alloy gears. It is likely that many more uses will be found for this class of work in the near future. So far they have been used for timing gears on petrol engines, brake-adjusting pinions, electric washing-machine gears, and the change-speed wheels on small lathes.

If required, the die-cast gear may be lightened, fixing holes can be cast, internal splines or tapers can be produced, and, if additional strengthening is necessary, the gear can be shrouded on one side. The large pinion on the right of Fig. 33 incorporates an accurately cast taper hole to suit a magneto spindle, and is also hollowed out for weight-saving purposes.

Internal gears are as easy to die-cast as external ones; further, gear forms can be included at the bottom of blind holes, and of course such details would be very difficult to machine. A slight draught must be allowed, but particularly in the case of external gears this need be hardly appreciable as the die-casting shrinks away from the mould during cooling. Bevel-gears, which do not grip the die as they contract, can be cast with a practically perfect tooth form.

It must be remembered that whichever way a gear is made,

some tool must be used to form the contours of the teeth, and for this reason it is not recommended that a die-cast gear be run with a cut gear. The die-casting will embody the characteristics of the tool which cut the die, and it cannot be expected that a die-casting produced in one works will run smoothly with a gear which has been machined in another factory. If for special reasons a die-cast and a cut gear have to work together, it is a good plan to give the die-caster details of the tool which cut the machined gear, so that a tool of the same make can be employed to produce the die-casting mould.

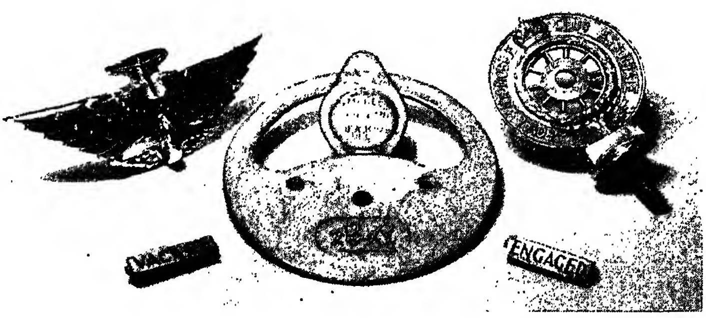
Gear forms produced as gravity die-castings in aluminium bronze, though not so accurate as pressure die-castings, are finding many applications, particularly where bevel-gears are required. The material is outstandingly resistant to wear and abrasion, and also to corrosion in such situations as arise in marine use where no lubrication is possible.

CHAPTER XVI

# Lettering and Decoration

OWING to the sharpness of detail which becomes attainable when die-casting is used, one frequently finds that engraving, lettering, decorative figures, mascots and so on are dealt with by this process. Fig. 36 shows a group of zinc-base alloy pressure castings, illustrating the results which can be obtained.

First of all, the designer should make sure that the presence of decorative features does not interfere with the opening and closing of the die. For instance, if a cylinder were to be die cast with a deep criss-cross knurling, the mould to produce it




*Courtesy of Fry's Diecastings Ltd.*

**Fig. 36.—Group of zinc-base alloy pressure die-castings illustrating the inclusion of lettering and ornamentation**

would be hopelessly complicated because with a normal two-part die the raised knurling in the vicinity of the parting plane would not "leave." Similarly, lettering could not be cast all round such a casting unless the die were arranged to have a number of radial core blocks.

A further consideration relates to the operation of die

making. It is easier to cut letters into a die than it is to machine away the majority of the die face, leaving raised letters. Because the die-casting represents the reverse of what happens in the mould, it will be clearly seen that it is easier to have raised letters in the die-casting than sunken ones. Like most things, it *can* be done if necessary; for instance, in Fig. 36, the "vacant-engaged" letters are sunk in the die-casting but the other details on the rest of the die-castings in this group were raised. There is another difficulty in the die-casting of sunken letters—the thin raised portion of the die is liable to crack owing to the continual impingement of the hot metal. Additionally the contracting die-casting pulls on to the raised portion of the die so that it must be expected that such a mould would need continual attention and replacement of the flimsy raised portion.

Sometimes it is necessary that lettering shall not project above the face of the die-casting. In such cases the lettering should still be cast raised, but it should be set in a sunken panel of greater depth than the height of the letters. Consequently the lettering will not stand proud; if the centre die-casting in Fig. 36 be examined it will be seen that the letters P & B have been produced in this manner.

It is essential that the die-caster should be consulted to decide the best place for lettering, and in the case of non-important details such as trade mark or part number, it is best to leave the allocation of position until the die has been designed. Accurately shaped lettering can only be die-cast if the mould moves in the direction perpendicular to the length of the word. If the letter is on a curved surface its shape may have to be amended to allow the die to "leave," but with skilful engraving it is surprising how lettering may be "faked" so that it can be cast on a curved surface and still give the impression that it is of normal shape. However, if lettering is required on a curved surface, bounded by a segment of more than 30°, the design should be carefully considered to see whether a rearrangement can be made.

Naturally, the pressure process offers the greatest scope for additions of decorative detail, but such work is often encountered in gravity die-casting as well. The maker's name and part number are the most usual markings, and provided the letters are not less than $\frac{3}{16}$ in. high, a clean impression will result, although it is difficult to get the dead sharpness of detail which is possible in pressure die-casting.

## Ornamental Parts

Ornamental parts are being die-cast a great deal these days. Although in a medium-sized country like this the demand for such articles does not always warrant the use of the die-casting process, in America the quantities involved permit the wide use of pressure castings. Readers will doubtless have seen elaborate cigarette lighters, one of which in particular takes the form of a knight in armour, whose visor conceals the lighter itself. This very interesting pressure die-casting is American, but a number of similar articles are being die-cast here and it seems likely that the process will be greatly extended in the future.

Automobile mascots and radiator motifs are frequently made as zinc-base alloy pressure castings; it is interesting to examine some of these and observe how they have been designed so that the mould will conveniently open and close. Dies for this class of work often call for the services of skilled engravers, and it is always wisest for the user to make up a model showing exactly what he wants so that the die sinker can decide where the parting must be. It is difficult, basing on a blue-print only, to determine whether an elaborate and ornamental mascot is practicable as a die-casting.

## Ejector Pins

This section applies almost entirely to the pressure process. The die-casting is usually arranged in such a way that when the die is opened the part will adhere to the moving half of the mould from which it is subsequently lifted by a number of suitably arranged ejector pins. These take the form of rods of a high quality steel which work in the die-block just as though they were cores. The ejectors are usually located on to a plate which can be moved backwards and forwards so that the operation of one lever brings all the ejector pins into action. While the die-casting is being produced the ejectors lie so that their faces are flush with the surface of the mould and when the casting is to be removed the ejector pins are pushed forward between $\frac{1}{4}$ in. and $\frac{1}{2}$ in., thus gently lifting the casting away from the surface of the mould. Because the die-castings are hot, the ejectors make circular impressions which remain visible on the finished article. Fig. 37 illustrates an aluminium-silicon alloy pressure die-casting for an electric motor body and this shows how the ejector pins are disposed to give the die-casting an evenly balanced push; two of the marks

are indicated by arrows. There are eight ejector pin marks visible around the rim, and it will be seen that special platforms have been arranged to give a substantial section on to which the ejectors can push. Another two ejector pin marks are visible near the central bearing hole.

Needless to say the user should watch that his die-caster does not allow the ejector pins to become worn; nothing in the

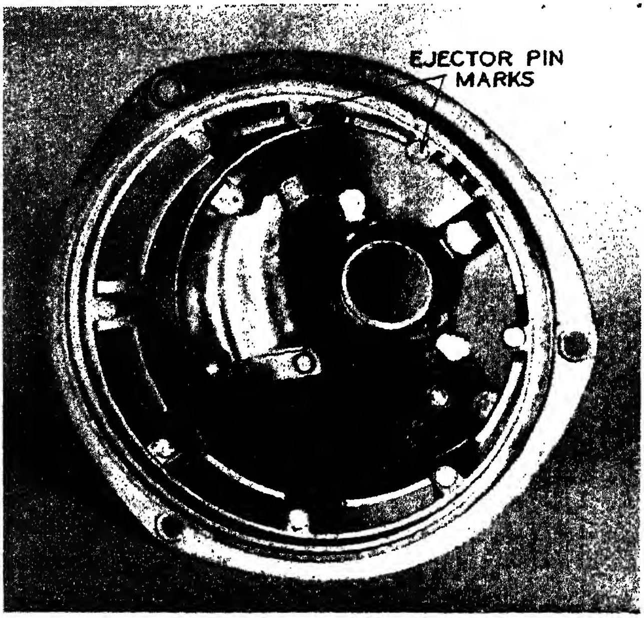



**Fig. 37.—Pressure die-cast aluminium alloy motor body illustrating ejector pin location**

nature of circular depressions or stumps should be present. Usually there is one-half of any article which is not specially exposed to view and in most cases the die-caster can arrange that the part is ejected on to a non-ornamental face. Occasionally he will arrange that an additional fin is included all the way round a die-casting and the ejectors push on to this fin which is subsequently removed by the trimming section. In this manner the finished die-casting is obtained without any visible sign of the ejector pins.

CHAPTER XVII

# Methods of Assembling Die-castings

IF it becomes apparent from the original design that two pieces would have to be assembled together, the immediate thought which should come to mind is: "Can the intelligent use of die-casting make the assembly into a one-piece job and thus dispense with the soldering, riveting, bolting, pressing, swaging or screwing operations which would otherwise be necessary?"

Although the ideal to be aimed at is the suggestion which has been recommended above, there are many cases where a one-piece die-casting is not practicable. For instance, it may be essential that the part contains an internal chamber which could not be cored in a single die-casting. Then, too, there are many cases where a die-casting (for instance, a decorative part) has to be attached to another larger body (such as a motor-car). This chapter will describe some of the methods which are available for joining die-castings on to other manufactured components.

## Soldering

Most alloys which are die-cast contain aluminium. Apart from the light alloys, we have the zinc-base alloys with 4% aluminium, and aluminium bronze with 10%. From the soldering point of view this is unfortunate, because when anything over 2% of aluminium is present the alloy takes on a thin film of aluminium oxide which forms so rapidly that it is practically impossible to make the surface of the metal chemically clean for soldering.

However, one or two special methods are available; for instance, aluminium solder may be used although this does not

seem to have anything like the popularity of tinman's solder Alternatively, the part can be nickel-plated and the die-castings soldered to the plated surface, but this procedure is the sort of thing which sounds all right but which is not really practicable. Another possibility is that the die-casting can be arranged to have a brass insert "cast-in" at the locality where the join is required. The soldering can then be done on the brass, but here again this method is more interesting than useful.

A good many years ago we worried a lot more about the soldering of die-castings than we do now. There are two reasons why the problem has become of minor importance. Solder is an alloy containing lead and tin, and these two metals are shunned in die-casting establishments which deal with zinc alloys, because if a minute fraction of 1% of lead or tin are allowed to become associated with the zinc-base die-casting production, the alloys will be ruined. When a certain number of die-castings are returned from the user to the supplier there would always be a chance of a soldered die-casting being remelted, thus being taken up by the alloy and making it useless. By avoiding the operation of soldering, the possibility of contamination in this way is minimised.

The second and still more important reason is that designers are becoming conscious of the fact that when they use the die-casting process with discretion it is possible to eliminate the operation of soldering. For instance, if a handle is contemplated being soldered on to a die-cast body, it will pay everybody concerned to consider the design with a view to embodying the handle as part of the die-casting.

It is quite likely that if it *had* been a very easy job to solder die-castings, users would have gone on being content with this method of assembling two parts. In a multitude of cases the difficulty of soldering has led or even compelled users to discover how they may avoid this operation by attention to design. Immediately this is done the advantages of price, appearance and reliability become still further emphasised.

## Riveting

If two die-cast parts must be joined together by a subsequent operation it is a useful idea to cast rivets integral with the one die-casting, and to produce holes in the item which is to be joined on to the former part. Fig. 38 shows a motor-coach ash

tray together with the three zinc-base alloy die-castings which featured in its construction. It is obvious that this ash tray could not have been produced in one or even two pieces on account of the shape of the ash container. Consequently, the portion is provided with rivets which will be seen at the corners of the body. Corresponding holes have been die-cast on to the flat plate which fits on the larger item. After chromium plating, the two castings are fitted together and the rivets pressed over.

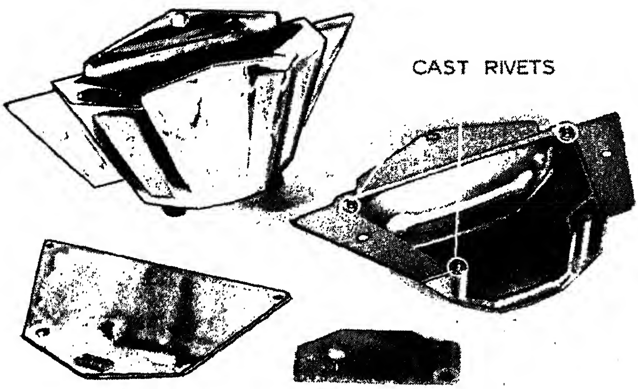



**Fig. 38.—Three separate die-castings which are assembled by means of rivets indicated by the arrows**

Those who have had experience with zinc-base alloys will appreciate that while such die-castings are ductile they do not permit of violent distortion, consequently rivets must be carefully designed. They must not be too long—only about $\frac{3}{32}$ in. to $\frac{1}{8}$ in. should project to be pressed over. The stud should not be a sloppy fit in the rivet hole, otherwise the riveting operation may give it several backward and forward knocks and cause a crack around the base. In any case the rivet stud should be radiused where it joins the die-casting, and the riveting operation should be more of a pressing than a hammering. Split rivets can be die-cast, but the observations expressed above should be borne in mind and the rivet should be arranged so that it is subjected to the minimum of distortion.

It is interesting that users tend to worry more about riveting problems in the winter than they do in summer. This is because at low temperatures the zinc-base alloys lose a considerable amount of ductility. However, the contrary holds, and increasing temperature increases the ductility. Consequently, if trouble is experienced in riveting, the die-castings may be heated in warm water for a few minutes before assembly, and so they become sufficiently ductile for the operation to be facilitated.

## Use of Cast-in Studs

Sometimes it is decided that the use of rivets is not desirable, and in this case brass studs can be cast as inserts into the die-casting, so that the article can be bolted into position. It should be remembered that the inclusion of the inserts reduces the speed of manufacture, but in some cases the increase in cost is worth while. A rivet cannot be dismantled without destroying the die-casting, and there is more likelihood that a die-cast rivet will be damaged during assembly than a cast-in stud.

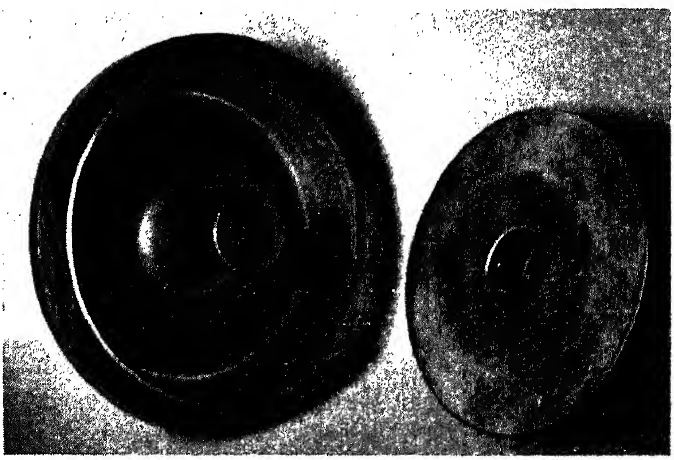


**Fig. 39.—Aluminium alloy pressure die-castings which are joined together by a spinning operation**

## Pressing and Spinning

Fig. 39 illustrates a case where two pressure die-castings in aluminium-silicon alloy had to be assembled to make a roller end. In order to save weight the part was made in two pieces

a bowl-shaped die-casting and a plate. It will be observed that a spigot is included round the rim of the former. The two castings are pressed together to make a closed chamber, after which the alloy is spun over the position of the spigot, and this forms a permanently "one-piece" job. Owing to the small grain size which is obtained in die-casting, such a procedure needs special precautions as the alloy hardens quite rapidly. However, if trouble is experienced, a low-temperature anneal is usually sufficient to make a spinning operation possible.

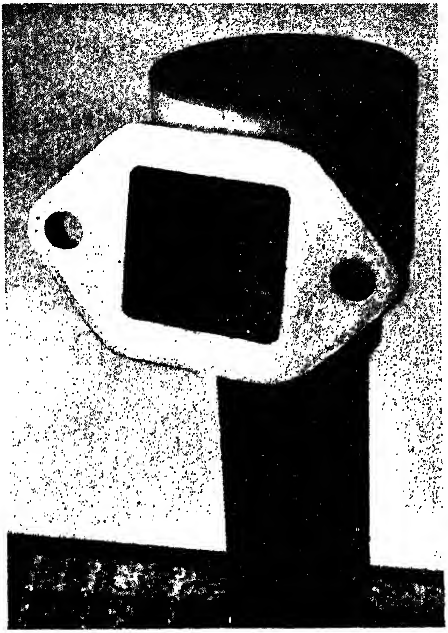


**Fig. 40.—Die-cast breather body with a long steel tube cast in as insert. A circular plate is pressed into the top**

If the article is not capable of rotation for spinning, two parts can be joined together in a press. Fig. 40 illustrates an interesting die-casting in zinc-base alloy where this operation was carried out. The die-casting itself consists of a body into

which a long bent steel tube is included as an insert. It will be seen from the photograph that the final article is practically closed, and it would not be possible to make such a job straight away as a die-casting; consequently, the one side of the body is left open and a disc made of zinc-base alloy is fitted into the circular spigot around the top. This is then pressed over to close the end (the complete job is shown in Fig. 28).

CHAPTER XVII

# Die Life

IT is characteristic of human nature that over a period of time we can get used to inconveniences which at first sight would seem intolerable. The steady increase of income-tax and the effects on die-castings due to wearing moulds may be cited as examples of this. However, the latter trouble can be minimised and, indeed, users should insist that their suppliers maintain their tools in such a condition that the die-cast product will not deteriorate over the years. One so often comes across cases where a dimension such as the diameter of a hole has been specified to be accurate to plus or minus 1 thou., but by the time the die has been in use for a year or so, the dimension has gradually varied from the original blue-print by 5 thou. or more.

## Effect of Quantity

It is unwise to save money on tool making unless the die-casting will definitely only be required in small quantities so that the effects of wearing dies will not be serious. In these days die-casting seems to be applied more and more to big quantity production and most jobs are so carefully planned that they may be expected to be used for a good many years without any drastic design changes. Partly as a result of this and partly on account of higher working pressures which are becoming used, there is a tendency these days for every pressure die-casting tool to be made in an alloy steel which is heat-treated before being set up for bulk production. This is universally true for the yellow metals and aluminium-base alloys, and a number of the leading die-casting concerns in this country are using heat-treated alloy steels for zinc-base production.

A die steel should be uniform and of good quality; sulphur

and phosphorous content should be as low as possible and the grain of the steel should be regular and without streaking. The composition, particularly the carbon content, should be precisely controlled. Usually the die is cut in the soft state; the first samples are run off from this tool and when the samples have been approved the die is heat-treated. It is dismantled for this operation and each component is carefully hardened so that the minimum of distortion occurs. The mould is re-erected and the various working parts "eased" or lapped as may be necessary to get a perfect fit.

A number of effects can take place in a die as it wears. The impingement of the alloy may cause hair cracks to appear on the face of the mould; this happens inevitably in the case of pressure die-castings in yellow metals. After a die producing brass pressure castings has been running for about 5000 shots, these hair cracks begin to appear; if the surface finish is not very important, the hair cracking does not matter and the die may continue to be used for another 15,000 shots or more.

Cores, particularly slender ones, will show signs of wear more rapidly than the main parts of the mould; their diameter becomes reduced due both to erosion and to the tensile effect of extracting the hot cores from the contracting die-casting. Another related effect is that cores become rounded at the extreme ends. This latter trouble means that if a long hole is produced by two cores which meet at the centre, deterioration of the die will result in a heavy flash at the point where the cores should have met.

## Precautions Against Wear

The die designer must foresee and take precautions to allow for the comparatively rapid wear on slender core pins and on any thin webs which produce narrow channels in the die-casting. Such fragile parts should, if possible, be located in the mould as far as possible from the point of entry of the molten metal so that the erosive effect and thermal effect are minimised. Provision must be made for the convenient replacement of such parts as they become worn. For instance, if a blind hole $\frac{1}{16}$ in. diameter is to be cored at the bottom of a recess 1 in. in diameter, the little pin which makes the small hole must be made separately from the main core and subsequently attached to it. If a stepped core were made from one piece of steel, the rapid wear of the small diameter part would mean the scrapping of the complete core.

However, as a general rule in pressure die-casting, the designer aims at constructing the mould in as few pieces as possible. If a die has to be built up from a number of awkwardly shaped parts, the continual fluctuation of temperature coupled with the impingement of the metal will, in time, allow the die-cast alloy to penetrate into the gaps between what might be called the built-up areas.

The biggest problem is that different pieces of steel behave differently; firstly when they are heat-treated and secondly when they are endlessly heated and cooled in die-casting. However closely the composition may be controlled, the contraction and the general behaviour will vary slightly from piece to piece. This becomes particularly marked when, say, a core pin produced from a round bar works in a die block produced from a forging, because the structure of these two pieces will be different owing to their varying methods of manufacture. It must not be thought from this that large dimensional variations take place, but even in well-made dies one must be prepared for minute effects such as those described above.

Fig. 41 shows two zinc-base alloy die-castings which had very

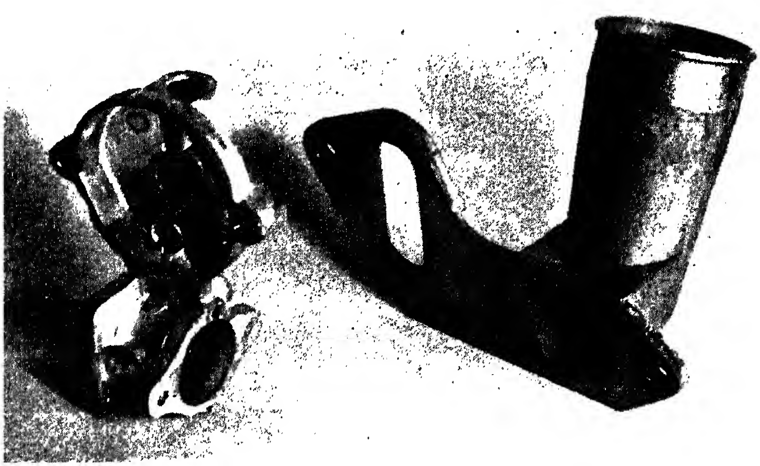


**Fig. 41.—Effect of design on die-life. The die-casting on the left had a die-life over five times as long as the part on the right**

widely differing " die-lives." At first sight it might seem that the carburettor cover on the left was the more complicated of the two but the die-life of this part has been well over a quarter of a million castings, while the component on the right started giving trouble after 50,000 shots. Examination of the photograph of this part will reveal a number of snags which led to the reduced die-life. The funnel portion is inclined at an angle to the plate, and consequently a two-piece mould with a straight parting line could not be used. There is a narrow slot which will be seen in the shadowed U-shaped recess, and the thin core producing this part gave considerable trouble. Further, a rim is required around the top of the funnel and as this could not be cast by the opening and closing of the die (because of its inclination), this rim had to be formed by two loose pieces. On the other hand the carburettor casting has all its die-movements at right angles to each other, the section is even and the die parting is straight. The mould producing this item will probably account for another quarter of a million.

It must be realised by users that the melting point of the alloy has an outstanding effect on the life of the tool. For instance, had the two items in Fig. 41 been made in aluminium, the small holes and slots could not have been cast, and even so the carburettor cover die-casting would have given trouble after 10,000 shots. Neither of these parts would be at all suitable to pressure die-casting in brass.

So far as the user is concerned the problem of die life can be summed up in two thoughts. Attention to design—choice of suitable section, eliminating of undercuts, careful consideration of cored holes—will result in long die life. When the user has done his job by paying attention to these points, it is up to the die-caster to maintain the die in such a condition that a die-casting examined three or four years after the placing of the order will be as accurate as the first few samples.

## CHAPTER XIX

# Cost of Die-castings

TO a great extent the question of price links up with the design considerations which have already been discussed, because, as has been repeatedly pointed out, careful designing has the effect of reducing cost. The relation between design and price will therefore be taken for granted, and it will be more the connection between quantity and cost which will now be considered. Die-casters practically never estimate their costs on a "per pound" basis; instead, the price of the die-casting is calculated. Usually a die-caster's quotation contains the "part cost of the necessary tool," together with the die-casting cost calculated per hundred or per gross. Users can generally appreciate why a tool cost is necessary, but it is sometimes difficult to understand why, when the tool cost has been paid, the cost of the castings can vary to a considerable extent with the quantities which are to be consumed. There are six factors which must be considered, and these will be discussed in turn.

### Raw Material Cost and Incidence of Overhead Charges

These first two factors are so obvious that they can be briefly treated. Raw material can be bought at a more advantageous price when purchased in bulk, and the allocation of overhead charges will be similarly affected. Office expenses come into the question to a considerable extent; practically as much time is taken up in discussing a small order by interview, letter and telephone, as is involved by a very large contract. Indeed, speaking as a member of a die-casting organisation, the writer would suggest that users who place large orders often cause much less trouble than customers whose requirements are limited to 500 die-castings per annum!

## Cost of Toolmaking, Setting-up, and Early Experimental Stages

It is somewhat difficult for users (particularly those who are new to die-casting ideas) to appreciate the heavy initial cost of pressure die-casting production. They cannot always understand why it may cost five times more to produce the first thousand die-castings than to produce the hundredth thousand. It might be interesting to catalogue the stages which are involved before output can be commenced with a pressure die-casting. Similar problems occur in the gravity process but the expense of die-making and setting-up is not nearly so great, consequently it is the pressure casting process which shows the most striking relationship between quantity and cost.

(*a*) On receipt of the order, the part is drawn out at the die-caster's works, showing exactly what he plans to produce. He will indicate taper on cored holes, draught on faces at right angles to the parting line, and allowance for machining, tapping, etc.

(*b*) The die is designed. Very often during this stage a few smaller points are discovered which will lead to further discussions between the die-caster and his customer. For instance, the position of ejector pins may have to be considered, or the die-caster may request that the taper in a particular hole shall go in a special direction.

(*c*) While the design stage is proceeding, the die-block forging has been ordered, and, when this is available, it is cut and ground so that its working faces are square. Next the dowel holes are developed and all important centres are located. After this the die-sinking proceeds. As a general rule the construction of a die is placed in the hands of one toolmaker, although he may be assisted by various turners, millers, and so on. Die-making can take anything from three days to six months, depending on the complexity of the job. Especially in the case of pressure die-casting there is a good deal of "invisible" work in the way of cooling channels, ejector pin mechanism, and core racks and pinions. This may explain why dies are sometimes thought to be more expensive than they are expected to be at first sight.

(*d*) When the tool is finished it is taken into the foundry and mounted on the machine. The die is warmed and given the first cast, using a reduced pressure of injection. Very often the first few attempts will only partially fill the mould, but the appear-

ance of the casting will indicate how the die must be adjusted to make it run correctly.

(*e*) When the venting and runner are satisfactory, and the cores and ejector pins are working easily, a few samples are run off for submission to the customer. As soon as these are approved the die is hardened and is now ready for bulk production. Unless one has seen a die-casting foundry it is difficult to realise that the early stages of production are like the running-in of a new car engine. It is a long time before full speed can be attained, and it also takes some days for the operator to get accustomed to the job. Consequently, the early output of a pressure die-casting may be very low indeed; by the second or third day it will have risen to one or two hundred, and during subsequent days the output will probably rise to over the thousand mark.

Figs. 42 and 43 show diagrams illustrating the stages in production of two die-castings—the first a pressure and the second a gravity product. From these diagrams it will be apparent why the gravity process is more suitable for small number production and the pressure method for large quantity output. Furthermore, the outstanding effect of quantity on the cost of the pressure die-casting will be appreciated.

Every time production stops it will take a certain amount of difficulty to get started again. Thus it will cost more to produce 12,000 castings at the rate of 1000 each month than to make all the lot in one run. It is for this reason that die-casters are willing to cast bulk quantities, stock them, and deliver them against schedule.

## Use of Multiple-impression Dies

Although the foregoing discussion has dealt with tools producing a single casting at each shot, it also applies to the working of a die which produces two or more castings at a time. Needless to say, the cost of a multiple-impression mould is more, and the setting-up time is a longer operation, but when 20,000 or more die-castings are required it will always pay to consider going to the expense of a die containing at least two impressions. Where several die-castings are needed to make up a set it is possible to group the parts into a multiple tool and so produce the whole assembly at one shot.

## Balance between Toolroom and Foundry

An average time for die-making is four weeks. During this time the work is in the hands of highly skilled men in a depart-

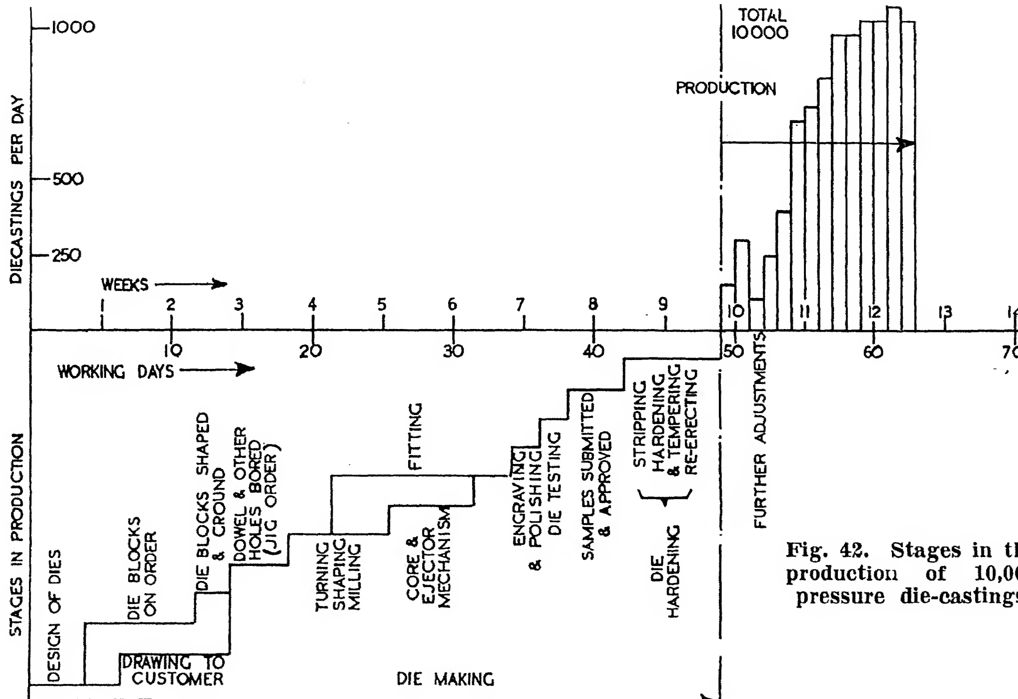



Fig. 42. Stages in the production of 10,000 pressure die-castings

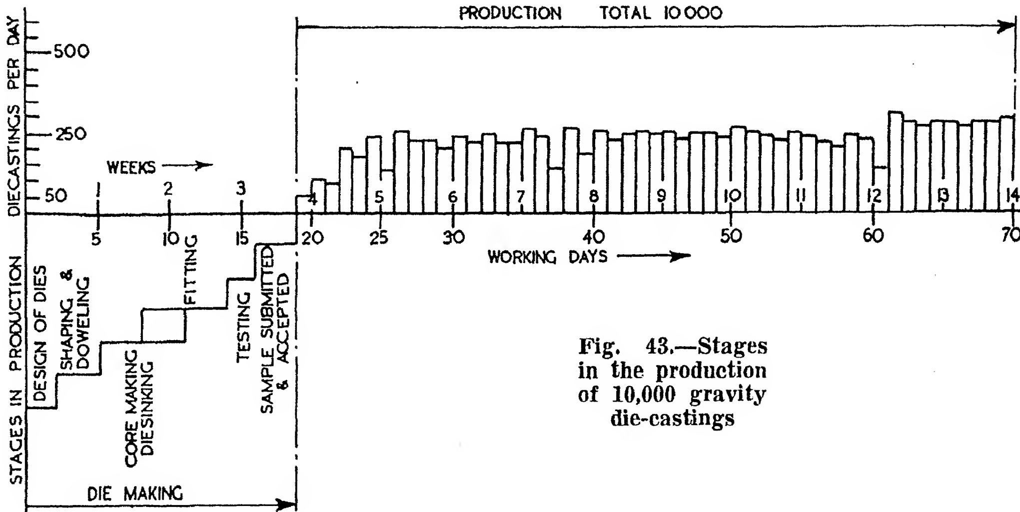



**Fig. 43.—Stages in the production of 10,000 gravity die-castings**

ment whose overheads will often be well over 150%—a department, moreover, which seldom shows a real working profit.

After the die is complete it is taken into the foundry and there it is used by semi-skilled operators whose purpose is to produce as many good castings per hour as possible. If a pressure die-casting order involves the production of only a thousand castings it is quite likely that the work will be in the toolroom for a month and in the foundry for perhaps three days.

If all die-casting orders were of this size, a producer's establishment would consist of a huge, expensive toolroom with a very small foundry tucked away in a corner. It is one of the die-caster's main problems to keep the balance between toolroom and foundry. Consequently, he endeavours to make sure of a certain number of jobs which will average at least 100,000 die-castings per annum. Once that firm basis has been established, the die-caster welcomes the receipt of orders for smaller quantities. It is for this reason that if a user feels able to guarantee the regular requirement of a certain die-casting he should make his producer aware, not only of the monthly deliveries which will be required, but of the total number of castings which will be absorbed in one or even two years. Basing on this, he should anticipate an attractive price being quoted.

## Possibility of Special Equipment Being Used

Most ordinary jobs which run to about 10,000 die-castings per annum do not permit the use of special handling or trimming equipment. Occasionally, however, when a large order is involved it pays to consider introducing clipping tools, and even in special cases a conveyor system which will take the castings from the machine to the trimming section. In the die-casting industry the use of special clipping tools has come very much into favour during recent years, but in this country the quantities involved hardly ever warrant the use of special conveying systems.

## Conclusion

It will have become apparent that especially in pressure die-casting the effect of quantity on cost is a striking one; consequently, it is to the user's advantage to give his die-caster full information about the quantities which will be absorbed over a period. The die-caster can always arrange to deliver specific quantities against schedule.

Needless to say, it would not be recommended that users give

fictitious ideas of their requirements! A producer who is sensible will have made an arrangement with his customer that if the quantities absorbed are less than those estimated, an extra charge will be made to cover the difference between the price calculated on the large quantities and the price which should have ruled on the basis of the smaller quantity which was actually taken.

Very often users, although wishing to take advantage of the low price attainable by considering large numbers, do not wish to commit themselves to taking these numbers at a time when the expected sales may be, at best, a matter of guesswork. In such a case it is a useful plan to obtain an estimate for the cost of repeat quantities. The initial order will be placed on the basis of the smaller number, but the user will have the knowledge that once this amount has been taken, the price will be considerably reduced. There is usually a clause in this arrangement which provides for serious fluctuation in the metal market which may have occurred in the meantime.

## CHAPTER XX

# Machining

IN an earlier chapter the subject of undercuts was considered, and it was mentioned that subsequent machining operations were inevitable if the undercut could not be avoided. Similarly, it may be necessary to machine an internal diameter to remove the slight amount of taper which is usually required to facilitate withdrawal of cores. In some cases threads, both internal and external, may have to be machined if it is thought inadvisable to die-cast these features. Very small holes are preferably drilled than included as part of the die-casting. Sometimes, of course, the die-casting may not offer sufficient accuracy for the work in hand, and a machining operation will be necessary for this reason. For instance, a gravity die-casting will have an accuracy of about plus or minus 0·005 in. per inch, compared with the products of the pressure process, which are usually accurate to about plus or minus 0·0015 in. per inch.

The dimensions of a die-casting should be arranged to be such that a minimum amount of machining is necessary. This is because the skin (particularly of a pressure die-casting) is much harder and finer grained than the interior, consequently it is to the user's advantage that as little as possible of this skin shall be removed by a machining operation.

It is a good plan to start with the absolute minimum of machining allowance, and if subsequently it is found that more metal is necessary, it is generally possible to arrange for this. Thus, the diameter of a core can be reduced, so giving more machining allowance on the hole; the die can be opened out if more allowance is required on exterior features. Readers will appreciate that it is simple to do this, while on the other hand, to *reduce* the machining allowance by *adding* metal to the die and cores would be a much more difficult operation.

If a die-casting is going to be drilled without a jig it is usually possible to "spot" the casting to give a positive location for the drill. On the other hand, if a jig is used for machining it is advisable to omit the spotting, because if the position governed by the jig is not exactly the same as the position given by the dimple, the drill may run off and break.

The various machining operations will now be discussed in relation to the die-casting alloys—zinc-base, aluminium-base, and aluminium-bronze. The writer hopes it will be appreciated that any suggestions can only be a matter of opinion, and machining practice varies quite widely, depending on the condition of the machine shop, the type of labour, and the individual die-casting which is to be machined.

## Zinc-base Alloys

The zinc-base alloys have never been considered troublesome from a machining point of view, although it has to be remembered that they possess a strange combination of toughness and softness which necessitates special precautions being taken. Speaking generally, high speeds and light cuts are recommended, and high-speed steel, stellite, or tungsten-carbide tools should be used.

Drilling can be done at high speed, but the drill should be kept very sharp. Although standard drills can be used, some machine shop foremen suggest that a quick spiral drill gives better results. In the drilling of small holes there is sometimes a tendency for the metal to pile up on the cutting edge, and it has been recommended that for holes up to ¼ in. diameter two-fluted drills are used, three-fluted drills for ¼ in. to ⅜ in. holes, and four-fluted drills for holes above ⅜ in. diameter. With regard to the angle of the point and the lip clearance angle, opinions vary; in particular for the latter some users recommend a lip clearance angle of 12°, while others say they can only get good results if this angle is increased to 20°. Suds oil, soft soap and paraffin are quite useful lubricants.

For turning, the rake should be high, a little higher than for mild steel. Cutting can be taken at about 150 ft. per min. For milling, a straight-toothed tool is often preferred to a spiral one, and it is suggested that face cutters or end mills result in a better finish than the use of cylindrical cutters. Speeds can be of the order of 300 ft. to 400 ft. per min., but the feed should be slow so that only a small amount of metal is removed at each cut. It is essential that the cutting edges should be very sharp.

An important point to note in the tapping of zinc alloy is the spinning effect which causes the metal to fill in the base of the thread. The tapping hole should be made larger than it would be in a harder metal; for example, if a tapping hole would produce a 65% thread in cast iron, a similar diameter in zinc alloy might have 85% to 90% thread. On account of the binding effect of the alloy it is recommended to use a tap in which the lands are reduced to minimise friction. It is a good practice to hook or undercut the cutting faces of the tap up to a maximum rake of 12°. Highly polished ground head taps are recommended where the best possible finish is required.

On account of the small taper which is necessary in coring holes, a reaming operation may have to be performed. Standard reamers can be used with success, providing the cutting edge is very keen. If trouble is experienced with binding of the tool, a reamer with narrow lands should be employed. For tapping, two-flute taps should be used, with turpentine or paraffin for a lubricant. For sources of further information on the machining of these zinc alloys, the reader is referred to the bibliography, page 156.

## Aluminium Alloys

There are a number of different aluminium alloys used in die-casting; some of these, such as the "L.8" composition, give very little trouble, but in particular the aluminium-silicon alloy has a tendency to drag, so that special precautions may have to be taken. In any case, the tool should be of the highest possible finish and should be kept sharp. As with the zinc alloys, high speeds and small cuts should be the general rule.

Standard drills can be used, and apart from remembering that aluminium alloys are classed as soft metals, there is little to worry about in the turning and boring. Milling sometimes gives trouble, particularly with the aluminium-silicon alloy. Cutting edges should be sharp and speeds fast (of the order of 300 ft. to 400 ft. per min.). To obtain the best results, finishing cuts should be light. Paraffin oil or cutting oil with lard oil addition are suitable lubricants.

## Aluminium Bronze

In both senses of the word, aluminium bronze is a "tough" proposition. The Brinell hardness of the alloy in its die-cast form is about 120, and owing to the presence of the beta constituent with a high local hardness, the wearing effect on tools is severe. Aluminium bronze should be treated as if it were a

combination of hard cast iron and of tough nickel steel. Fast working speeds should not be attempted, and the cutting rate rarely exceeds 100 ft. per min.

It is essential that any tool used on this alloy should be very sharp. Drills should be of the slow helix type and of good quality steel. Some users find that it is a good plan, when grinding the point of the drill, to skim off the extreme end of the "hook." It may be found better to feed the drill intermittently, using ample lubricant such as paraffin.

For turning, the machine should be run at low or medium speed, and either high-speed steels or Widia tools give good results. On account of the toughness of the alloy it is often found best to have no top rake or even a negative rake on the cutting tool. The operation of turning should be controlled so that the metal comes off in short chips and not in coils. In this, as in other machining operations, a squealing note from the cutting tool means that something is wrong somewhere.

In milling aluminium bronze the speed should be slow, of the order of 80 ft. to 100 ft. per min., and cuts should be light. It is best to use fine-toothed cutters, otherwise the tool will chatter.

The tapping of aluminium-bronze die-castings presents quite a number of difficulties, and in many cases users have found that if they employ taps such as are used for brass the tool will stick solid in the bronze die-casting. The best results can be obtained with a two-fluted tap with the top rake flat and the smallest possible amount of land.

Sometimes it may be considered advisable to heat-treat this alloy to improve its machinability. A simple softening treatment consists of heating the alloy to 700-750° C. for 1½ hours (taking precautions not to exceed 800° C.), the die-castings are then cooled slowly down to about 400° C., and subsequently cooled in air. This treatment will remove the majority of the hard constituent and make possible fast machining.

CHAPTER XXI

# Plating of Zinc-base Die-castings

PROVIDING zinc-base alloys are regarded as a class by themselves which needs individual treatment, it is possible to obtain a very good and durable plated finish. If, however, a user persists in treating his zinc-base die-castings in the same vat and with the same solution as he is using for plating brass articles, he must expect to get mediocre results.

It is definitely to the advantage of the user that a separate equipment is installed, and that the polishing, cleaning and plating sections are kept devoted to the finishing of the die-castings. This means that a manufacturer who is only purchasing small quantities of die-castings will probably not be justified in doing his own plating. However, not only are the majority of die-casters prepared to supply the plated article, but there are a large number of industrial platers who make a speciality of zinc-base work.

To get the best results, attention should be paid to each stage of the treatment. It is so very easy, if a plated die-casting comes out pin-holed, or if the plate strips, to blame the die-caster, and to rely on the age-old excuse that "there must be something wrong with the metal." Before condemning the metal or the die-caster it is usually advisable to check up the various finishing processes. The stages in plating are discussed below, and because there *are* occasions when "there may be something wrong with the metal," this point will be discussed first.

## Condition of the Die-casting

To obtain a satisfactory finish it is important that the die-casting is solid. Most pressure castings have got a solid-looking skin which is obtained by the rapid chilling of the alloy against the die face, but it is much more difficult to ensure that the interior of the die-casting shall be sound. If pin-holes exist

about $\frac{1}{64}$ in. below the surface it is likely that polishing will remove the outer skin, so that the plating solution penetrates into the holes and causes blistering. The solidity of the die-casting, therefore, should be the first consideration.

The second important point where metal affects the plating is the actual composition of the alloy. In these days no reputable die-caster uses anything but alloy containing zinc of greater than 99·99% purity, and with modern methods of production it is practically certain that no inclusions will be present in the die-cast product. However, there are three zinc alloy die-casting compositions which are widely used, containing about 2·8%,

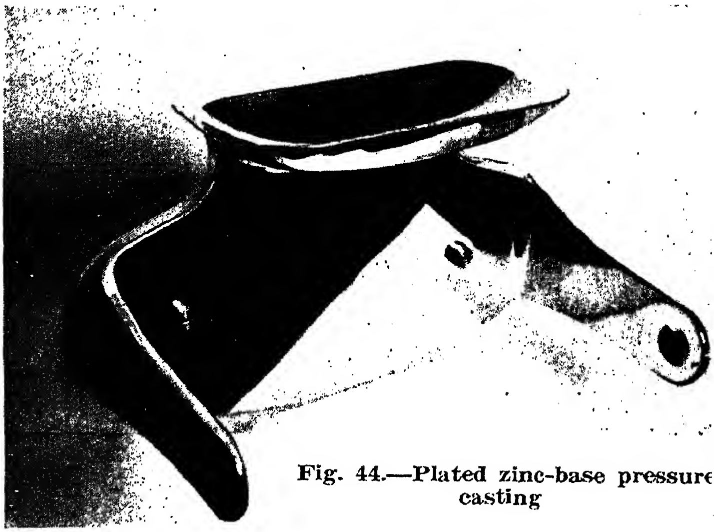


Fig. 44.—Plated zinc-base pressure casting

1%, and no copper respectively. With decreasing copper content the hardness also decreases, and many platers feel that it is easier to polish the low-copper alloys than the older and stronger alloy with the 2·8% copper. Consequently, if it is felt that the metal is giving trouble it may be advisable to enquire whether the die-caster can arrange to use an alloy with 1% or no copper, so as to get improved results so far as the plating is concerned.

## Polishing

Many plating troubles go back to the polishing operation. If possible, the polishing should not remove the hard outer skin,

and of late there has been a tendency to decrease the amount of polishing. If grinding is necessary (for instance, if the remainder of a heavy flash has to be removed), it may be done on a felt or canvas wheel to which emery is glued; the grinding surface speed will be between 5000 ft. and 6000 ft. per minute. It is important that this treatment is not too drastic and the emery should not be coarser than 140. Buffing is done with cloth wheels at a speed between 8000 ft. and 9000 ft. per minute, and tripoli abrasive is used.

## Cleaning

Two kinds of cleaner are employed; organic solvents which remove grease without attacking the metal, and alkaline solutions which remove grease and may also attack the metal. In recent years the solvent trichlorethylene has been widely used. Some platers get good results with an electrolytic alkaline cleaner alone, but precautions have to be taken that this is arranged to give the maximum action in the shortest possible time, otherwise the die-cast alloy will be attacked. One of the causes of unsatisfactory plating is over-cleaning, and it is likely that an organic cleaner followed by a rapid alkaline treatment will give the best results. Good results can be obtained by an additional dip in 10% hydrofluoric acid, with a similar dip after copper-plating.

Following the cleaning, it is most important that the casting is thoroughly rinsed, particularly when it is complicated in design. It may be found preferable to give first a hot and then a cold rinse. The casting should then be immersed in an acid dip, followed by a further rinse. Dilute sulphuric acid or hydrochloric acid with a hydrofluoric acid addition are both used, while some platers use just a 1% solution of hydrofluoric acid.

## Copper-plating

A few years ago many platers felt that it was unnecessary to copper-plate zinc alloy die-castings before nickel-plating, but now the wheel has come full circle and most people recommend quite a heavy copper deposit. There are a number of proprietary copper solutions on the market, and providing these are used to the makers' instructions there does not seem to be much difficulty. Some platers advocate their copper solution to be run at temperatures ranging from 110° to 180° F. Different users copper-plate for anything from a minute to a quarter of an hour; it seems likely that for best results it is necessary to apply about 0·0005 in. of copper, followed by not less than the same thickness of nickel-plate.

## Nickel-plating

In recent years there has been a tendency for manufacturers to specify the thickness of plate which they require. This has been welcomed by most people who are connected with die-casting because it reduces the possibility of the zinc-base alloys falling into disrepute through defective plating. For ordinary work the nickel-plate should be not less than 0·0005 in., while in special cases—for instance, automobile fittings—0·00075 in. should be specified.

Practically every manufacturer of plating materials is only too glad to supply information and special solutions for the nickel-plating of die-castings. One of the reasons why ordinary brass solutions cannot be successfully used is that the acidity should be different when zinc-base alloy is to be plated. The *p*H value of the solution should be regularly checked; depending upon the solution which has been supplied, it will vary between 5·3 and 6·0, the usual value being 5·5.

It might be mentioned that some platers continue to apply direct nickel without a preliminary copper deposit, as they contend that the absorption of the copper by the zinc is deleterious. In such cases the nickel is struck at high current density, subsequently reducing the current. However, in any process it is only to be expected that opinions will differ! The tendency at the present time is for the use of heated and agitated solutions. A further development has been the use of the bright nickel-plating process.

## Chromium Plating

Providing the previous treatment has been carried out satisfactorily, there is nothing special to say about chromium plating, as no individual precautions are necessary to differentiate zinc alloys from other metals. It must be realised that the chromium is not essentially a protective coating, but consists of a criss-cross network of extremely hard crystals which augment the durability given by the nickel-plate. Usually chromium plate is applied to a thickness of between 0·00002 in. and 0·00003 in., and it might be mentioned that there are some solutions available for the direct chromium plating of zinc-base alloy die-castings.

## Stripping

A number of people feel that if a die-casting has to be stripped it will never again be possible to give it a satisfactory re-plate. This is probably true in the case of die-castings which

are porous underneath the skin, because the second polishing operation will be bound to reveal even more pin-holes; nevertheless, there are occasions when a die-casting must be stripped through no fault of the die-casting. The chromium plate is removed by making the work the anode in a hot alkaline solution, and the nickel and copper are stripped in sulphuric acid solutions which sometimes contain nitric acid too. For more detailed discussion on the subject of plating, the papers given in the bibliography, page 157, should be of value.

CHAPTER XXII

# Combination of Plastics with Die-castings

THE moulded products are substances which under the influence of heat and pressure become plastic, so that they may be moulded in dies to form solid articles. They can be divided into two main classes—" thermo-setting " and " thermo-plastic," according to the effect which heat has on their constitution.

## Thermo-setting Compounds

When a thermo-setting compound is moulded at high pressure under the influence of heat the powder becomes plastic so that it takes the form conferred by the mould. Shortly afterwards, while the process is still continuing, the compound changes in its chemical constitution and becomes a hard substance which does not soften by the further application of heat and pressure. This subsequent hardening occurs gradually and occupies anything from half-a-minute to half-an-hour, depending on the compound which is used, the moulding temperature and the size and thickness of the article. Once made, the moulding loses its plastic properties so that scrap cannot be re-used as can be done, for instance, in the casting of metals.

Bakelite is, of course, the best known member of the thermo-setting group. It is principally composed of the organic chemical compound phenol formaldehyde which is produced when phenol (a coal tar product) and formaldehyde (obtained from wood spirit) are heated together in the presence of ammonia.

Another widely used compound in the thermo-setting group is urea formaldehyde, better known as "Beetle." This takes

practically the same time to cure as bakelite but is about twice as expensive in raw material cost. It has the advantage, however, that being of a clear colour it can produce translucent glass-like mouldings or can be tinted with light colours such as pink, blue or green. Bakelite, on the other hand, being itself amber-coloured, can only be supplied in a range of more sombre tints.

These two groups of formaldehyde resins are usually blended with a filler such as wood flour, which binds the compound together and confers strength to it (the moulding powder is supplied ready blended). For special purposes other fillers may be used such as asbestos, fibre, stranded fabric or paper pulp, according to the mechanical properties which are required. Depending on the compound and on the filler the tensile strength of a moulded thermo-setting composition will vary from 2 to 5 tons per sq. in.

## Thermo-plastic Compounds

Celluloid and glass are two well-known thermo-plastics and they illustrate the difference between this group and the former, for while the action of heat makes them plastic and subsequent cooling causes the substance to return to a hard condition, the process of moulding does not cause the property of plasticity to be destroyed. A thermo-plastic may be used over and over again. The product known as "cellulose acetate" is probably of major importance from our point of view.

The compound in the form of a powder is fed into a hopper, then introduced into a cylinder closed at one end, except for a small orifice, and is provided with a piston. The cylinder is heated to a temperature of between 140° and 160° C. by means of an electric element. The material when sufficiently heated becomes plastic and is then forced by means of the piston through the nozzle into the mould. A working speed of from two to four shots per minute is quite usual. The operation of injection moulding is very similar to pressure die-casting, and indeed die-casting machines can be adapted to it.

## Coating of Die-castings with Thermo-plastic Compound

From the point of view of the user of die-castings the most interesting possibility of cellulose acetate is the moulding of

the compound around a die-casting, thus giving a coloured finish of a pleasing, warm texture. The illustration, Fig. 45, shows several parts which have been treated in this way. One uncovered die-casting is shown in the centre and surrounding it are die-castings which have been covered with mottled, opal and gold plastic finishes.

A die is constructed having the same form as the casting but slightly larger in its dimensions; the die-casting is anchored inside this mould so that there is a small gap all round it, and into this gap the thermo-plastic is injected under a pressure of 6 to 10 tons per sq. in.

An important factor in the covering of a die-casting is the injection points (*i.e.*, the exact position at which the cellulose acetate is injected). Care must be taken when designing the

*(Courtesy Lacrinoid Products Ltd.)*

**Fig. 45.—Pressure die-castings covered with injection-moulded plastic**

mould that sufficient injection points are allowed so that the material is given every assistance to cover the die-castings in the fraction of a second during which the operation takes place. If sufficient injection points are not allowed, the die-casting will not be completely covered, or a seamy appearance will be shown if the material cools before the final covering has taken place.

Naturally the die-casting cannot be covered entirely as some support must be given to certain points to locate it in the mould. Also, care must be taken that these supports are suffi-

cient in number and at the correct position, so that the die-casting does not become displaced when the compound is injected.

Cellulose acetate is superior to the thermo-setting compounds in its electrical resistance and strength. Further, a wider range of colours is available. On the other hand the raw material cost is greater (possibly because the thermo-plastics are used in the raw state without fillers), but owing to the fact that the speed of moulding is very much higher they are surprisingly economical in use. There is no limit to the thickness which may be applied to a die-casting providing the injection machine has sufficient power to overcome shrinkage on thick sections. However, as the cost of the material is an important factor, a thickness of 0·07 in. is rarely exceeded. It is wise not to go below 0·03 in. Cellulose acetate may be moulded on to aluminium die-castings, as well as the zinc-base group, providing the aluminium alloy is not too soft. The writer is indebted to Messrs. Lacrinoid Products Limited for a great deal of the information which is contained in this article.

CHAPTER XXIII

# Inorganic and Organic Finishes for Zinc Alloy Die-castings

THERE are few finishes which cannot be applied to a zinc alloy die-casting, although it is admitted that certain treatments are more suitable than others. A number of representative processes are discussed below, and the bibliography, page 157, gives particulars of where detailed information can be obtained. Several inorganic finishes will be mentioned first, after which organic coatings will be discussed.

## Chemical Finishes

Most of the chemical compounds of zinc are white; consequently if an inorganic coloured finish is to be applied, either the alloy must be plated with another metal such as copper, which is then subjected to a finishing process, or the coloured compound of another metal must be chemically deposited on to the zinc.

**Black.**—An ebony black may be produced by cleaning the die-castings and immersing them in the following solution:

Water—1 gal.
Hydrochloric acid—1 fluid oz.
Copper nitrate—1 oz.
Ammonium chloride—1½ oz.
Cupric chloride—1 oz.

The solution should be used at 100° F. After drying, the parts are brush finished and then heated to 160° F. for a quarter of an hour. The die-castings are then dry scratch-brushed, following which a coating of lacquer is applied.

There are several other chemical processes for applying black and also some electrolytic ones. A typical electrolytic black is as follows:

The solution is made of composition—

Nickel ammonium sulphate—8 oz. per gal.
Zinc sulphate—1 oz. per gal.
Sodium sulphocyanate—2 oz. per gal.

This solution is worked at 113° F., current density 1 to 2 amp. per sq. ft., and plating continues for about 2 minutes.

**Brown.**—Usually this is formed by some solution which will deposit cuprous oxide, for example, by immersing the die-casting in a solution containing 2 lb. copper nitrate in 1 gal. of water. This coating must be protected with lacquer.

**Bronze.**—A process which is widely used consists of copper plating the zinc-alloy die-casting and treating the plated article with ammonium or other sulphide solution.

**Lighter Colours.**—For producing blue, the die-castings are cleaned and immersed in a solution containing 10 oz. cobalt chloride, 10 oz. ammonium chloride, in 1 gal. of water. If a purple is desired a similar process is used, but instead of the cobalt chloride an equal amount of nickel ammonium sulphate is used. In this case the solution is warmed to 140° F. and the treatment takes from 3 to 5 minutes.

Readers who are interested in obtaining a range of colours might experiment with the following solution:

Water—1 gal.
Caustic soda—2 lb.
Copper tartrate—1½ lb.

This is held at between 80° and 100° F., the colour on the zinc changes and, depending on the time of immersion, yellow, light brown, crimson, blue, purple and green can be obtained! The higher the temperature the brighter will be the colour, but above 100° F. the transition from one colour to another occurs so rapidly that the process is difficult to control.

## Enamel Finishes

To one who is not connected with the manufacture of enamels it is difficult to obtain what may be regarded as the "last word" on the subject. Every manufacturer naturally recommends his own particular brand, the composition of which is rarely specified; moreover, there is considerable divergence of opinion about the necessity for pre-treating the die-casting before any coating is put on it.

**Pre-treatment of the Surface.**—There are two reasons why it is often recommended that die-castings should be pre-treated before an enamel is applied. The first is that etching of the surface is in many cases reported to improve the adherence of enamel to a die-casting; the second reason is that on exposure to the atmosphere, the metal oxidises and eventually forms a

zinc carbonate. It has been suggested that even when the die-casting is covered with a layer of enamel, the carbonate forms and reacts with chemicals in the enamel so that the coating becomes loose after a few months. For these two reasons it is widely recommended that quite apart from the usual degreasing prior to enamelling, the zinc-base alloy should be pre-treated. Coslettising, parkerising and granodising are generally used for this pretreatment.

At the same time, speaking as a layman with regard to the science of enamels, the writer would remark that he has come across several cases where die-castings have not been pre-treated, apart from cleaning, and where the adhesion of the enamel has been extremely good at least a year after the finish has been applied. It may be certain that certain enamels need a pre-treated surface and some corrosive conditions also necessitate this pre-treatment. On the other hand, for ordinary usage there appear to be several synthetic enamels supplied by many well-known makers which give good and permanent adherence, even though the die-casting is not pre-treated.

**Application of Enamel.**—It might be mentioned here that all enamels which are applied to zinc alloy die-castings must be of the air-drying or low-temperature stoving type; the baking temperature of such enamels rarely exceeds 250° F. It is not even necessary to bake all the enamels which are used, but the air-drying finishes are not so hard or durable as an enamel which has been stoved. The most usual method of applying the finish is by spraying, although certain straightforward shapes lend themselves to a dip method. Spraying gives superior results, is faster, and in many cases proves to be cheaper than the dip process. Quite often it is found that a single spray will be sufficient, although for light tints such as blue, a double application is preferable.

## Combination of Electroplate and Enamels

Attractive results can be obtained by the combination of plated and enamel treatment; in particular many motor bonnet decorations incorporate this kind of finish. Where the surface to be enamelled is relatively large, special synthetic enamel is applied which is capable of being buffed after baking. It is usually the raised features which are plated and these high-lighted parts are pumiced without affecting the adherence of the remainder of the enamel. The nickel plate is then applied.

When the plated area is to be larger than the enamelled

portion the plating is done first. The surface to be left bright is either masked before spraying or the whole die-casting is sprayed and the surface which is to remain bright is immediately wiped clear. In other cases the enamel is applied with a brush on just those localities where it is required. It will be appreciated that when the enamelling is done on top of the plate, the baking temperature must be as low as possible in order to avoid blistering the plated surface.

## Other Organic Finishes

Lacquers differ from enamels in that the fundamental process taking place during drying is evaporation only. Many so-called cellulose enamels are really lacquers. The older type gum lacquer is occasionally used as a final coating over chemically coloured die-castings, but in these days the cellulose or synthetic lacquers are coming more into favour as they have a better appearance. It does not seem to be so necessary to pre-treat a die-casting before lacquer is applied. There are a number of useful finishes on the market, and various bronze, black, coloured or metallic lacquer finishes can be used. Zinc alloy die-castings which are polished but not plated can be protected with a coating either of lacquer or of a clear synthetic varnish.

If a hard and enduring finish is required a high-grade japan may be used. The japan is baked at about 300° F., so one essential of the die-casting should be that it is free from blowholes, otherwise the comparatively high temperature will cause the air in such cavities to expand and cause bubbles on the surface. The resultant finish is tough and adhesive and has a high lustre which can be restored by buffing if the part becomes dull by exposure. On account of the temperature of stoving, it is sometimes recommended that the copper-free zinc-base alloy is employed, as this suffers less from the action of elevated temperatures than the copper containing alloys.

The finishing of zinc-base alloy die-castings has not yet been fully explored, and there are wide possibilities, particularly in the combination of two or more different effects. From time to time entirely new processes are reported, most of which are interesting. For instance, in the paper by Kellers given in the bibliography, page 157, a method is described which makes it possible to imitate grained wood, marble, etc., and in the literature which is regularly issued by the New Jersey Zinc Company of America, various finishing processes are frequently dealt with.

CHAPTER XXIV

# The Finishing of Aluminium Alloy Die-castings

THE thin film of oxide on aluminium is not unsightly and consequently there are many cases where aluminium alloy die-castings can be used without a protective finish; this is particularly true of the aluminium silicon alloys, whose resistance to corrosion is very good.

On occasion, however, where special protection is necessary, or where a particular appearance is desirable, the die-castings can be treated in a number of ways. Thus, vacuum cleaner parts are polished; washing machine components may be enamelled; a number of die-castings are chemically or electro-chemically treated if they have to work in corrosive conditions; decorative parts are sometimes anodised and tinted, and domestic aluminium-ware may be chromium plated.

## Polishing

Aluminium die-castings which are polished retain their brightness for long periods and this is aided by the fine grain-size which exists at the exterior of the die-cast product. If grinding is required it is done on a felt, canvas or calico wheel to which emery of between 120 to 150 mesh is glued. The surface speed should be about 5000 ft. per min. Afterwards the castings are bobbed with felt bobs using a rather finer emery. For buffing, the wheel is made up of sewed bobs and the surface speed is about 5000 ft. per min. A final "colouring" operation gives a bright finish to the article, this being done on a larger wheel giving a speed of about 8000 ft. per min.

The castings may be given a satin appearance by scratch brushing or sand-blasting. If it is required to have a contrast between polished and matt surfaces on the same die-casting, the article can be polished and then certain parts are covered

by glueing thick brown paper on to them. The exposed surfaces are then sand-blasted, after which the paper is removed, leaving a sharply defined demarkation between the polished and matt areas. A frosted effect may be obtained by an alkaline dip followed by an acid dip. A subject which would repay study is the barrel finishing of aluminium die-castings. The parts are placed in a closed barrel and packed with small steel balls; the barrel is rotated and the movement of the balls give a high polish to the articles. It is interesting that castings which have been treated in this way have an extraordinary resistance to corrosion.

## Plating

The rapidity with which the oxide skin forms causes difficulty in persuading an ordinary nickel deposit to adhere to the aluminium. Consequently the plating of the metal must involve an initial treatment which cleans and plates at the same time, *i.e.*, which prevents oxide formation, whilst metal is being deposited on to the surface of the aluminium. After degreasing a thin film of zinc or iron is usually applied in this manner, following which the article is nickel plated. The nickel plate should be rather thicker than usual--of the order of 0·002 in.

There are difficulties in the way of plating aluminium. For instance, if the initial solution is incorrect in composition the oxides may be incompletely removed. Other problems may arise as the various constituents of the alloy may be attacked to different degrees; it is partly through the latter trouble that much more has been heard of the plating of pure aluminium than of aluminium alloys. However, basing on some experience with plated die-castings, the writer suggests that nowadays it is definitely possible to get a good plate on die-castings in aluminium alloy, providing these are reasonably solid. It is possible to plate aluminium not only with nickel but with copper, rhodium, silver, brass, cadmium, etc. The author is obliged to Cromalin Limited for most of the information contained in the above section.

## Anodising

Although the ordinary oxide film which forms on the metal is fairly continuous it is not sufficiently thick to act as a permanent protective coating. Anodising processes, greatly stimulated by Dr. Bengough's work on the chromic acid method, are designed to form by electrolytic means an integral film of oxide of ½ thou. or more in thickness. Two classes of

process are widely used—the Bengough-Stuart process employing chromic acid, and the sulphuric acid variety. Another method using oxalic acid is less popular. In many cases inhibitors are added to the electrolyte to obtain differences of film structure, thus producing varying properties in the film mechanically and chemically.

The work is fastened to aluminium racks and is made the anode, while the lead-lined tank (containing the electrolyte) acts as cathode. In the Bengough process the current is usually D.C., while in other methods A.C., D.C., or a combination of both are used. Referring to the Bengough method, the electrical resistance of the article is at first very low and consequently the striking voltage will usually be less than 4. As soon as the oxide film commences to form, the resistance rises and as it does the voltage is pushed up until the final voltage will be of the order of 50 (the treatment lasts about an hour). The process presents certain production difficulties but it is widely employed. Not only has the oxide film resistance to wear and corrosion but it is of such a texture that it can be dyed so that the article can be coloured with attractive tints. The sulphuric acid method is much easier to work and is more applicable to castings because it is possible to treat a wider range of alloys. Also the current density remains practically the same throughout treatment. Colours obtained by this method are translucent and are inclined to appear brighter than those produced from the chromic acid vat. Most of the popular aluminium alloys can be at least protectively anodised, duralumin, hiduminium, birmabright, L.5, etc.

It will be apparent to anyone who has come in contact with the beautiful results which anodising can produce, that the possibility of treating die-castings in this way is more than interesting. However, the use of die-castings presents three main snags:

(1) It is essential that the die-casting be free from blowholes, otherwise the acid may penetrate into such cavities and afterwards cause trouble by seeping back on to the surface after the article has been put into use.

(2) The composition of the alloy has a profound effect on the anodising treatment. In particular when an alloy is duplex in structure the anodised film may also be duplex. Thus, for instance, the alloy containing 12% silicon contains two constituents and this means that although an anodic film can be

applied to such an alloy it will not be homogeneous and consequently when the film is tinted the colour will not be uniform. It is mainly for this reason that the majority of die-casting alloys which are anodised and tinted contain low percentages of alloying elements (less than 6%).

(3) The third factor affects the preparation of the alloy for the anodising process. A die-casting consists of a hard outer skin of fine-grained structure, while the inside which is not so rapidly chilled is softer and of larger grain size. The polishing of die-castings to prepare them for anodising is liable to remove the skin unequally and therefore it may happen that in one locality the original fine-grained skin exists, while in another spot where the polishing has been more severe the interior will be revealed. This means that the anodised film would not be perfectly homogeneous and thus a certain amount of patchiness will occur.

The difficulty which has just been described seems to concern pressure die-castings more than gravity castings, and it may be the chief reason why the anodising of the former has lagged behind that of the latter. However, during the last few years careful consideration has been devoted to the polishing and anodising of pressure die-castings and special alloys have been developed which are both suitable for the pressure process and the anodising process. The writer is grateful to Anotints Limited, of Birmingham, for a great deal of the information which is contained in the above section.

In Chapter XXIII, dealing with the finishing of zinc alloy die-castings, the question of enamelling, lacquering, etc., was gone into quite fully, and it may be taken that those remarks apply in a large measure to the treatment of aluminium alloy die-castings.

CHAPTER XXV

# Inspection of Die-castings

THE aim of any inspector is to serve his firm best by seeing that the maximum quality of goods are supplied with the minimum piling up of expense. When an inspector who works on these lines checks over a die-casting, he attempts to bear in mind, firstly, any special limitations of the process; secondly, he should visualise what the article is going to do in service. Thus, if certain holes are very important both with regard to diameter and distance between centres, the die-caster should be warned that the inspection will be rigid on these features. If, on the other hand, a web which has been introduced for strengthening purposes has a $\frac{1}{4}$-in. radius where it joins the main section, an inspector who rejects a casting because this radius happens to be a shade oversize would be nothing but a liability to his own firm.

## Alloy Specification

Whether or not the alloy should be specified depends upon the job. For instance, if an aluminium part has just got to act as an end cap and is practically unstressed, it would be foolish to insist that such a part should contain exactly 11·7% silicon and have a tensile strength of precisely 12·5 tons per sq. in. The imposition of such a stringent specification for such an unstressed part would probably just about double the cost of the die-casting without accruing any really useful benefit from the increase in cost. On the other hand, if it is known that a component is subjected to severe conditions, it is best to give an alloy specification, always bearing in mind the metallurgical problems of the metal which is being die-cast.

For example, in the use of aluminium alloys, although the analysis of any important die-casting should be defined, it should be remembered that small variations of composition

rarely have any appreciable effect on the properties of the product. Thus, for instance, it does not really matter whether an aluminium silicon alloy contains 11·5% or 12·5% of silicon, because the properties of both compositions are almost identical.

When we come to the zinc-base alloys, however, the exact analysis of the metal is of extreme importance. Firstly, the zinc should be greater than 99·99% purity, and secondly, the percentages of the added elements should be controlled to close limits. Thus the aluminium content of the alloys is usually specified as being 4·1%. If by an error the zinc-base alloy contained 4·5% aluminium, the alloy would be quite noticeably embrittled. The composition of the zinc alloy should be discussed with the die-caster in the light of the use to which the article is to be put. Thus, if the alloy has to be riveted, spun or twisted after die-casting, the designer would do well to specify the alloy with 4·1% aluminium and no copper, rather than the one with 4·1% aluminium and 2·7% copper.

With regard to impurities, it should be remembered that practically every alloy "takes an objection" to certain metals which are deleterious if they accidentally become present. For example, 0·002% of tin in zinc alloy would ruin the die-casting, but ten times this amount of iron would not be specially serious. In brass, 0·25% of iron might be a welcome addition, but 0·1% of bismuth would be objectionable.

## Physical Properties

A die-casting for making, say, an electric motor body or a pinion for a washing machine is not tested, but instead a sample of the metal from which it was made is taken, cast or machined into the shape of a test-bar, put into a special machine and pulled until it breaks. This, the common tensile test, cannot be expected to reproduce the conditions which the component has to withstand in use, although, of course, to those who can interpret test figures with imagination, the tensile strength, elongation, hardness and impact resistance give quite a useful indication of how the metal will perform in service.

With die-castings there are some special problems which rather reduce the value of ordinary tensile tests. The skin of a die-casting is harder and stronger than the interior; consequently, if it is ⅛ in. in section, the die-casting will be stronger per unit of cross-sectional area than a test-bar which is 0·25 sq. in. at its narrowest portion. This is because in the diecast section there will be a greater proportion of stronger metal.

Certainly the last word has not been said about the physical testing of die-castings. Stringent specifications should only be issued when the part is of vital importance and the user can afford to pay accordingly. (This remark applies not only to die-castings but to all products which are inspected.) At the moment there is an encouraging tendency for die-casting specifications to be issued in collaboration with those who have had long experience with the properties of die-castings, and it may not be very long before there is a complete set of special die-casting specifications which take into consideration the very individual properties which these products offer.

## Solidity

The idea of buying a casting of any kind is to buy metal and not blowholes. When an ordinary foundry casting is purchased by the pound, blowholes are not paid for, but die-castings, being bought at so much "per each," mean that the user pays good money for cavities if the die-casting happens to be anything less than solid. Seriously, the user would do well to make up his mind that ordinary pressure and gravity castings can and should be solid, and he should insist that this is so throughout the run of the job.

A good start is important, and when a new die comes into operation the user should ask his die-caster to submit samples and the article should be sectioned at all important points to make sure that cavities have been eliminated. Certain elaborate shapes, particularly those which include heavy sections, present serious difficulty with regard to porosity, but it should be remembered in such cases that even if unsoundness cannot be entirely eliminated, an alteration to the runner and venting should succeed in removing local porosity from any specially important position. Particularly in the case of aluminium alloy and brass pressure die-casting the use of high working pressure makes it more likely that solidity will be achieved.

## X-Ray Inspection of Die-castings

When any die-casting is cut up to see if it contains cavities, that die-casting is destroyed. Apart from taking the specific gravity, which does not indicate the locality of unsoundness, the only way of determining whether all of a batch of castings are solid is to cut them up and so destroy them all. During recent years the method of examination by X-ray has become

interesting, and although it is not widely used at present, more may be heard of it in the future.

If a die-casting containing blowholes is held in a field of X-ray emanation, the rays will pass more easily through the holes than through the metal. The absorption of the X-rays increases logarithmically with the amount of metal traversed, so that if at any point the rays pass through a blowhole, there

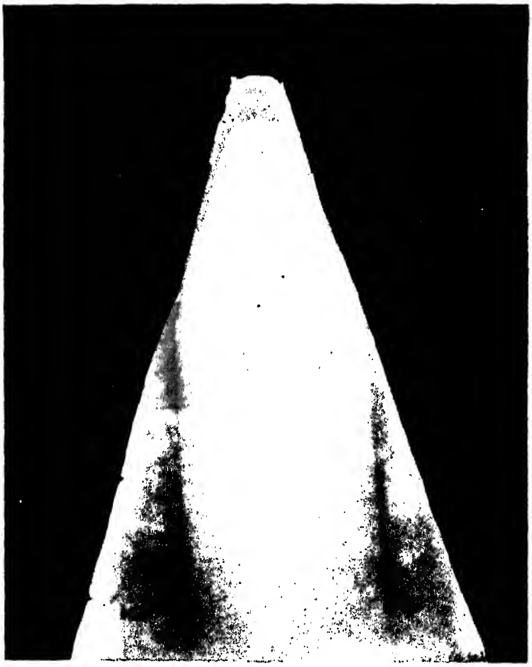


**Fig. 46.—An X-ray photograph of an aluminium alloy die-casting made at low pressure; porosity is shown by light patches**

will be less absorption than where the emanation passes through solid metal. An X-ray photograph of such a die-casting, therefore, will reveal the presence of cavities as dark spots on the negative and light spots on the photograph.

The absorption of the rays is approximately proportional

to the fourth power of the atomic number of the base metal and is inversely proportional to the cube of the applied voltage. This means that zinc alloys will be more difficult to X-ray than aluminium. The beauty of X-ray examination is that it gives a complete internal picture of the condition of a die-casting, while sectioning only reveals porosity which comes in the line of a sawcut. The

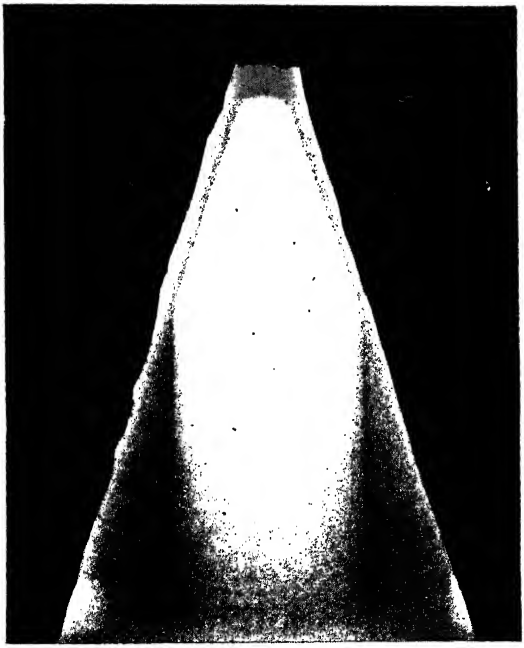


**Fig. 47.—Another X-ray photograph of a similar aluminium alloy die-casting but this time made at high pressure. The improvement in soundness is apparent**

writer has only had experience with the photographing of X-rayed die-castings but understands that several types of apparatus are now on the market for performing the visual examination where the X-rayed image is cast on a fluorescent screen. The illustrations show two X-ray photographs of

aluminium alloy pressure die-castings. That in Fig. 46 was cast at low pressure, and porosity will be seen as light patches on the photograph; the casting shown in Fig. 47 was produced at a considerably increased pressure (of the order of 2 tons per sq. in.) and the photograph shows that unsoundness has been very much reduced.

## Dimensional Checking

All dimensions which are of importance should be carefully marked on the blue-print which is issued to the die-caster. This is not to say that other dimensions will be inaccurate, but the holding of very tight limits all over the die-casting involves careful checking both at the die-caster's and at the user's works, and this labour is superfluous if the part has only three or four really important dimensions.

If the die-casting is going to be used for a long run, it pays to bear in mind that if any wear does occur in the die it will have the effect of causing exterior dimensions to become slightly larger and cored recesses to become reduced in diameter. This is generally carefully watched by the die-caster, and cores are renewed at intervals. Sometimes three or four sets of core pins are required during the long life of a die. If a user notices that cored holes are becoming much more tapered than they were originally, or if a flash develops at a locality where two core pins meet, he will know that wear is taking place in the die, and the matter should be taken up with the die-caster at once.

CHAPTER XXVI

# Should a User Make His Own Pressure Die-castings?

THE position which is to be discussed arises from the fact that there are a number of large organisations in this country whose consumption of die-castings is very big; sometimes one firm will have as many as a hundred dies in regular use. Many of these companies purchase the whole of their die-casting requirements from trade houses, a few manufacture practically all their own die-castings, while others make certain items at their own works and purchase other parts from outside die-casters.

First of all let us examine the reasons for using "home-made" die-castings. To make sure that the statement of the position is a fair one, the writer has asked members of several firms, who do their own die-casting, to give their reasons for doing so. Their answers are summarised below.

## Users' Opinions

(1) Companies are sometimes in the position of requiring very large quantities of three or four simple items which are wanted in such numbers that it is quite certain that a die-casting machine could be run in full-time operation. In such a case, providing there are members of the organisation who know enough about die-casting to get reasonably satisfactory results, it may be felt "worth while" for the user to install a machine.

(2) It sometimes happens that a company has a large quantity of patterns which are only required in quite small lots. The firm wishes to have all these produced as die-castings but finds that, on account of the small numbers which are needed from each die, the price quoted by a commercial die-caster is considered to be too high. Consequently, the user

installs a small die-casting plant and calls on his existing tool room to make the numerous dies which will be required. He then produces small quantities of the various parts as and when they are needed. This gives the advantage that when, say, a small quantity of these fittings are urgently wanted to oblige an important customer, the user can run off the parts on his own die-casting machine, whereas it might have taken somewhat longer to get the small order fitted into a commercial die-caster's production. The expense of setting up for the small lot would probably be counted worth while to keep the good faith of the customer. (The writer cannot forbear to interpose and say that he does not agree with the above point of view. In cases as described above, the home product usually costs more than it would if a suitable die-caster had been chosen who would be willing to make the various small quantities at a reasonable price. Also it is unfair on one die-casting machine to expect it to produce a whole range of sizes and designs.)

(3) Occasionally special die-casting jobs are needed which present such individual problems that they are best dealt with by the user at his own works. For instance, in the making of certain types of pressure cast rotors, which include large numbers of pressed steel laminations as inserts, the user sometimes makes both the laminations and the die-castings in his own establishment. This would get over the difficult problems of transport and packing of the laminations, checking dimensions of inserts, etc., which arise if the important inserts had to be despatched to the die-caster.

(4) There is a type of firm who make it their policy to manufacture as much as possible on the premises. If this is the sole reason for making their own die-castings, it is a bad one, and the general opinion is that in such a case the user will never fully obtain the benefits which the use of die-castings can make possible.

## The Die-caster's Point of View

An overwhelming majority of die-casting users purchase from trade houses. This is not because an ordinary intelligent set of people could not succeed in making quite satisfactory die-castings if they set their minds to it, but because most users have decided that it pays them to purchase from a specialist producer. The following are the main reasons which are advanced.

(1) In die-casting you do not just pull a handle and the finished product comes out the other end. The problems of die design, tool making, machine construction, metal melting and control of the die-casting plant, make the work a full-time job, calling for the skilled application of both engineering and metallurgical knowledge. The process has not yet been reduced to the application of a few formulæ, but every die-casting presents its own individual problems. Consequently, the general opinion is that the community who spends its lifetime in an atmosphere of die-casting should be more successful at the job than a firm who have been brought up on the manufacture of pianos or electric locomotives.

(2) The die-casting plant, as installed by a user, generally consists of between one and six machines. The plant of most commercial die-casters ranges between 30 and 60 machines, and this gives the most valuable quality of flexibility. The machines will be of a whole range of sizes, and each type will be specially designed for undertaking a particular weight and class of job. Thus, a 2 oz. zinc alloy die-casting with no cored holes, a 6 oz. one with holes in three directions, a lead alloy part, a brass pressure die-casting, a large aluminium pressure casting and a zinc alloy job weighing nearly 20 lb. would each be manufactured on different sizes of machine. Only a specialist producer could be expected to have a plant which is suitable to the undertaking of all kinds of jobs.

(3) Die-casting is a new industry in which developments and improvements are continually taking place. The specialist who has a large plant working full time can afford to keep abreast with improvements, and scrap old machines and purchase improved types. The manufacturer who has bought a couple of die-casting machines at a cost of several hundred pounds each, cannot afford to dispense with them six months later, even though a revolutionary improvement may have come along rendering his two machines obsolete.

(4) When one is doing nothing but die-casting it is easier to get a true idea of cost than when the die-casting plant is fitted into a corner of the factory. For one thing the die-caster will have a better idea of the depreciation of machine tools, dies, pressure casting machines and melting plant.

There is another point which manufacturers who make their own die-castings do not always consider. Die-casting takes a lot of supervision. In the case of a die-casting firm, the expense

of the staff can be calculated and allotted its true part in the overhead charges. On the other hand, if a plant has been installed in a manufacturing works, it very often happens that the proprietor, general manager and works manager, with a total income of £2000 upwards, may, almost without noticing it, spend many hours of their valuable time trying to get the die-casting plant to run smoothly. It is only because die-casting is such a fascinating process that chief executives often will not let themselves realise how much time they are wasting in the die-casting foundry.

## Conclusion

If any country in the world should be in a position to have understood the possibilities of die-casting, that country is America. The quantities which are consumed are so very large that it might be thought that every manufacturing concern could run its own die-casting establishment. Although four or five years ago this *was* the trend in the U.S.A., the tendency has veered right round and now there is a smaller percentage of American manufacturers doing their own die-casting than there is in this country.

At the same time, the position here seems to be settling down to a reasonable level. Certain firms who have the special circumstances described at the opening of this chapter make their own die-castings, and a number of them do quite well; because they are tackling just a few problems continually, they can install the right plant to do the work successfully. Except in these special cases, it is usually found best to purchase die-castings from an outside producer.

Die-casting to-day plays such an important part in production economies that a healthy die-casting industry is essential to the general well-being. Any increase in "home" production should be discouraged because it tends towards stagnation. Only a live, prosperous die-casting industry can afford to develop so that this country is as well served with die-castings as are America and Germany.

# A Bibliography of Die-casting

### BOOKS ON DIE-CASTING


HANDBUCH DER SPRITZGUTZTECHNIK. By Leopold Frommer. Published by Julius Springer, Berlin (1933). Price about 90s. 686 pages. 244 illustrations.
Treats in great detail die-making, machine design, elimination of porosity, alloys and design, etc.

DIE-CASTINGS. By Herbert Chase. Chapman & Hall Limited. Price 17s. 6d.
An interesting book of 264 pages with many illustrations, tables and drawings. The subject is treated from the user's point of view. Applications, alloys design, inspection and finishes are comprehensively dealt with.

DIE-CASTING. By Charles O. Herb. Industrial Press, New York City, and in this country by Machinery Publishing Company. Price 14s.
300 pages. Deals with die-castings from the producer's point of view. Pressure casting machines and design of dies are considered in detail. There are interesting sections on brass die-casting, vacuum die-casting and the die-casting of cast iron.

DIE-CASTING; DIE-CASTING DIES; DIE-CASTING MACHINES. "Machinery's" Yellow-back Series. Price 2s. 6d. each.

ALUMINIUM BRONZE. Issued by The Copper Development Association, Thames House, Millbank, London, S.W.1.
Although this does not exclusively deal with die-casting it is of very real value to any user of aluminium bronze.

TECHNOLOGIE DER ZINKLEGIERUNGEN. By Arthur Burkhardt. Published by Julius Springer, Berlin. Price about 45s.
Comprehensive treatise on zinc-base alloys. 256 pages, 411 illustrations. Deals with constitution of alloys, fabrication, machining and finishing. Although the book does not exclusively deal with die-castings the subject is considered in detail.


### GENERAL


DESIGN OF PRODUCT TO UTILISE DIE-CASTING INSTEAD OF MACHINE PARTS. By Louis H. Morin. Amer. Soc. Mech. Eng. Preprint 1932.
Properties of various die-casting alloys.

OPERATIONS ON WIRELESS COMPONENTS (DIE-CASTING). Anon. "Machinery," London, 1933; vol. 41, p. 637.
Die-casting as used in the manufacture of a tuning condenser.

DIE-CASTING. By F. A. W. Livermore. "Mechanical World," 1933; vol. 93, pp.165-167.
General consideration of design of die-castings. Minimum size of holes, wall thickness, etc.

ARTISTS AND ENGINEERS CO-OPERATE IN PRODUCTION OF DIE-CASTING HARDWARE. By J. B. Nealey. "Iron Age," 1933; vol. 131, pp. 740-742.
American application of zinc alloys to manufacture of motor-car fittings. Composition, properties and finishing are discussed.

DIE-CASTING METALS SET NEW STANDARDS. Anon. "Machinery," New York, 1933; vol. 40, pp. 101-103.
Written from American point of view. Applications of various die-casting alloys.

NOTES ON THE DESIGN OF DIE-CASTINGS. By F. A. W. Livermore. "Metal Industry," London, 1934; vol. 44, pp. 341-343.
Advantages of die-casting. Details of venting, ejectors and casting of threads are considered.

DIE-CAST WHEEL HUBS AND CAPS. By E. Stevan. "Mechanical World," 1935; vol. XCVII, p. 5.
An example of the use of die-casting for the production of parts commonly made by pressing.

METALS USED IN DIE-CASTING. By Charles H. Hughes. "Machinery," New York, 1936; vol. 42(7), pp. 446-449.
Composition and properties of 25 die-casting alloys which are in general use.

DIE-CASTING. Anon. "Mechanical World," 1937; vol. CII, pp. 125-127 and 149-150.
A review of German practice including a classification of available alloys, principles of the various types of die-casting machines, and essentials for successful die design and plant operation.

DIE-CASTING. By Arthur Street. Jnl. B'ham. Met. Soc., 1937; vol. 17, No. 4, pp.155-176.
Lecture and discussion to the Birmingham Local Section Inst. of Metals.

APPLICATIONS OF DIE-CASTING. By Arthur Street. "Metal Industry," London, 1938; vol. 52, No. 1, pp. 11-14.
Illustrated article reviewing scope of die-casting.

"MACHINERY'S" DIE-CASTING SUPPLEMENT. (Each month since November 4, 1937.) Can be purchased separately. Price 6d. each.
Designing for die-casting, application, alloys, production, die-making, machining and finishing, theories of die-casting, die-casting machines, and future possibilities are treated.

## GRAVITY DIE-CASTING

(see also Light Alloys and Copper-base Alloys)

PRODUCTION OF GRAVITY AND PRESSURE DIE-CASTINGS IN ALUMINIUM. By C. Vaughan. "Metal Industry," London, 1932; vol. 42, pp. 125-126, 150-153, 179-180.
Lecture before London Section of Inst. Prod. Engrs. Design of dies, cores and pouring for gravity die-casting. The pressure process is also described.

DIE-CAST PISTONS. Anon. "Automobile Engineer," 1933; vol. 23, pp. 161-164.
Alloying, melting, die-making and casting for pistons in Y-alloy and Lo-Ex. Heat treatment also described.

GRAVITY DIE-CASTINGS. By E. C. Lewis. Jnl. Coventry Eng'g. Soc., 1934. November-December.
A practical paper describing gravity production. Alloys, die construction and pouring are described.

PERMANENT MOULD CASTINGS IN ALUMINIUM. By R. J. Roshirt. "Iron Age," 1936; vol. 138, pp. 50-52 and 134.
Reasons why gravity castings may be preferred to pressure ones.

HAND-OPERATED MOULDING DIES. By T. K. "Mechanical World," 1935; vol. XCVIII, p. 602.
A small hand-operated bench machine for gravity-casting lead vice-jaws.

SLUSH DIE-CASTING. By E. Stevan. "Mechanical World," 1936; vol. C, p. 638.
A special application of the gravity process with hand-operated dies for the production of hollow-ware.

PERMANENT MOULD FOR CASTING SCREW KNOBS. By E. S. "Mechanical World," 1936; vol. XCIX, p. 88.
Hand-operated dies using gravity process.

ALUMINIUM GRAVITY DIE-CASTING. By J. J. Mills. "Metal Industry, 1939; vol. 54 (25) pp. 655-658 and vol. 55 (1) pp. 11-13.
Gravity die-casting at the Leyland Motor Works. Illustrated.

### PRESSURE DIE-CASTINGS

(See also Zinc, Light Alloys, Copper and High-melting-point Alloys)

DIE-CAST SCREW-THREADS. Anon. "Machinery," London, 1933; vol. 41, pp. 529-530.
Methods of constructing dies for producing threaded die-castings.

KIPP DIE-CASTING MACHINES FOR SMALL PARTS. Anon. "Machinery," New York, 1933; vol. 39, pp. 483-484.
Brief description of pressure die-casting machines.

MODERN DIE-CASTING MACHINES. By E. Stevan. "Metal Industry," London, 1934: vol. 45, pp. 363-365.
Mechanical and hand-operated die-casting machines.

A PRODUCTION CASTING DIE. By E. Stevan. "Mechanical World," 1934; vol. XCV, p. 425.
An example of a set of dies for pressure casting in zinc-aluminium-copper alloy.

THE PRESSURE DIE-CASTING OF ALLOYS. By Ladislav Jenicek. "Metal Industry," London, 1935; vol. 47, pp. 411-416.
Paper presented to International Foundry Congress at Brussels, April, 1935. Types of pressure machines reviewed and various alloys are considered.

PRINCIPLES OF PRESSURE DIE DESIGN. TECHNIQUE FOR VARIOUS DIE-CASTING ALLOYS. By E. Stevan. "Metal Industry," London, 1935; vol. 47, pp. 579-582.
Factors to be considered in die design. Die steels. Methods of die-parting, core removal, etc.

A BRIEF STUDY OF AMERICAN DIE-CASTING MACHINES. By Herbert Chase. "Metal Industry," London, 1936; vol. 48 (17), pp. 481-484.
Illustrated article describing the principles of a number of American machines.

FORMING A DOUBLE-SQUARE CORE. By E. S. "Mechanical World," 1935; vol. XCVIII, p. 82.
Details of dies for car handles in zinc alloy.

STEELS USED FOR DIE-CASTING DIES. "Machinery," New York, 1936; vol. 42 (6), pp. 369-371.
Symposium of opinions of some American die-casters. Composition and Brinell hardness of suitable die steels are given.

LUBRICATION OF DIE-CASTING MOULDS. By E. S. "Mechanical World," 1937; vol. CI, p. 160.
Practical methods used in dealing with problems encountered in the quantity manufacture of small articles of hardware.

MOULD CORES FOR DIE-CAST HALF-BEARINGS. By E. S. "Mechanical World," 1937; vol. CI, p. 416.
An example of the type of problem often raised by special-purpose dies.

DIES FOR CASTING BEARING SHELLS. By E. S. "Mechanical World," 1937; vol. CII, pp. 510-511.
An example of the use of small hand-operated plunger-type die-casting machines.

THE PRESSURE DIE-CASTING IN MODERN INDUSTRY. By Herbert Chase. "Engineering," 1937; vol. 144, pp. 613-615 and 643-644.
Properties and applications of chief alloys and account of die-casting practice in the U.S.A. (with emphasis on zinc-base alloys).

PRESSURE DIE-CASTING. By Hans Lawetsky. "Metal Industry," London, 1938; vol. 52 (13), pp. 359-363.
Report of lecture to Lond. Sec. Inst. Prod. Engrs. Descriptive of high-pressure machines.

DIE-CASTING EQUIPMENT AND PRACTICE IN THE UNITED STATES. By Herbert Chase. "Engineering," 1938; vol. 146, pp. 293-295, 306, 411-412.
Die-casting plants described. Trend towards use of higher injection pressures. Magnesium die-casting.

HIGH-PRESSURE DIE-CASTING MACHINES FOR HIGH AND LOW TEMPERATURE ALLOYS. Anon. "Machinery," New York; vol. 44 (10), pp. 692-694.
Madison Kipp "cold chamber" machines; illustrated.

DIE-CAST KEYS. By E. S. "Mechanical World," 1938; vol. CIII, pp. 320-321.
Details of dies for multiple production in the small Madison-Kipp machine.

PROTECTIVE DRESSINGS FOR CASTING DIES. By E. S. "Mechanical World," 1938; vol. CIII, pp. 491-492.
Methods of protecting iron and steel of dies against the action of molten metal.

## ZINC-BASE ALLOYS

THE NEW JERSEY ZINC ALLOY POT. Distributed in this country by Imperial Smelting Corporation Limited, 95 Gresham Street, London, E.C.2.
An interesting regular trade publication, giving modern applications of zinc alloys and discussing their finishing, machining and design. Occasional numbers contain a bibliography of American literature.

"METALGRAMS." Published by the Apex Smelting Company, 2554 Fillmore Street, Chicago, U.S.A.
A series of tables and graphs issued at intervals, recording properties of zinc-base alloys after periods of treatment in water vapour. In each case figures are given showing effect of varying casting temperature, die temperature and injection pressure.

ZINC ALLOYS FOR DIE-CASTING RECENTLY IMPROVED. By J. B. Nealey. "Metal Progress," 1932; vol. 22, pp. 43-46.
Properties of zinc-base alloys and improvements effected by use of purer zinc. Machining and finishing of die-castings.

TOUGH, STRONG, PERMANENT DIE-CASTINGS. By D. L. Colwell. "Metal Progress," 1933; vol. 24 (6), pp. 19-23.
The article was written at the time when "99.99 plus" zinc was becoming universally employed, and it stresses the stability which arises from the use of pure zinc.

ZINC DIE-CASTING ALLOY, AGEING DATA. By E. A. Anderson and G. L. Werley. "Metals and Alloys," 1934; vol. 5, pp. 97-99 and 102.
Dimensional changes in zinc-base alloys at room temperature and 95° C.

DIMENSIONAL CHANGES IN DIE-CASTING ALLOYS (Meta-stable Beta phase in aluminium-zinc alloys). By R. G. Kennedy, Junr. "Metals and Alloys," 1934; vol. 5, pp. 106-109 and 124-126.
Effect of temperature and composition on decomposition of the beta phase. Constitution of zinc-base alloys.

THE EFFECT OF VARIATIONS IN ALUMINIUM CONTENT ON THE STRENGTH AND PERMANENCE OF THE A.S.T.M. No. XXIII DIE-CASTING ALLOY. By E. A. Anderson and G. L. Werley. Proc. Amer. Soc. Test. Mat., 1934; vol. 34.
Impact strength of copper-free alloy was measured with aluminium content varying between 4.3% and 4.8%. Owing to the fact that impact strength is reduced with higher aluminium contents the authors conclude that aluminium should not be greater than 4.3%.

THE IMPACT STRENGTH OF COMMERCIAL ZINC ALLOY DIE-CASTINGS. By E. A. Anderson and G. L. Werley. Proc. Amer. Soc. Test. Mat., 1934; vol. 34 (2).
Charpy impact tests on zinc-base alloys with 4.1% aluminium and 0-2.8% copper.

THE ZINC DIE-CASTING ALLOYS CONTAINING ALUMINIUM. By A. Burkhardt. "Metallwirtschaft," 1934; vol. 13 (35), pp. 607-612.
Published in English translation by British Aluminium Company Limited. Miscellaneous publication. No. 264; October, 1934.
Effect of impurities on ageing and loss of impact strength of zinc alloys.

STUDIES OF PHASE CHANGES DURING AGEING OF ZINC ALLOY DIE-CASTINGS. By M. L. Fuller and R. L. Wilcox. Amer. Inst. Min. Met. Eng. Technical publication No. 572. "Metals Technology," September, 1934.
Study of constitution of zinc-base alloys with special reference to beta phase.

PHASE CHANGES DURING AGEING OF ZINC ALLOY DIE-CASTINGS. By M. L. Fuller and R. L. Wilcox. Amer. Inst. Min. Eng. Technical publication No. 657. "Metals Technology," December, 1935.
Dimensional changes on ageing attributed to changes in alpha phase.

THE DIE-CASTING OF NON-FERROUS METALS (II). THE ZINC-BASE DIE-CASTING INDUSTRY. By D. Kirkwood, Junr. "Metal Industry," London, 1935; vol. 46, pp. 61-63.
Properties of zinc alloys. Influence of impurities on impact strength. Finishing.

ZINC-BASE ALLOYS AS SUBSTITUTES. By A. Burkhardt. "Zeit. f. Metallkunde," 1936; vol. 28 (10), pp. 299-308. Translated and abridged in "Light Metals" research, 1936; vol. 5 (6), pp. 140-141.
Constitution of the zinc-rich zinc-aluminium-copper alloys.

THE MANUFACTURE OF HIGH-PURITY ZINC AND HIGH-GRADE ZINC DIE-CASTING ALLOYS. By D. S. Burwood. "Metal Industry," London, 1936; vol. 48 (16), pp. 455-457.
Fractional distillation process for producing "99.99 plus per cent." quality zinc. Manufacture of zinc-base alloys.

ZINC DIE-CASTINGS. By Herbert Chase. "Automobile Engineer," 1936; vol. 26, pp. 496-500.
Use of zinc alloys in American automobile industry.

DIE-CAST RADIATOR GRILLES. Anon. "Automotive Industry," 1936; vol. 74 (2), pp. 44-47.
Illustrated description of zinc alloy grilles as used on 12 models of American cars. Weights of various grilles and louvres are tabulated.

REVIEW OF THE FIELDS IN WHICH ZINC DIE-CASTINGS ARE USED. By Herbert Chase. "Metal Industry," London, 1936; vol. 48, pp. 582-584 and 635-637.
Zinc die-castings as applied to automobiles, ciné cameras, typewriters, toys, etc.

SHRINKAGE OF DIE-CASTINGS. By E. S. "Mechanical World," 1937; vol. CI, p. 220.
Mould and core adjustments for zinc-base alloys.

INVESTIGATIONS OF THE CASTING BEHAVIOUR OF ZINC ALLOYS. By A. Burkhardt, F. Huth, E. Koops. "Zeit. f. Metallkunde," 1937; vol. 29, pp. 380-388. Translated B.N.F.M.R.A. Miscellaneous publication No. 339.
Physical properties, fluidity and castability of zinc alloys. Authors recommend alloy with 4.0% aluminium, 1.0% to 1.5% copper, 0.03% magnesium. Sand as well as chill casting is described.

ZINC-BASE DIE-CASTING ALLOYS. By H. L. Evans. "Metal Industry," London, 1937; vol. 51, pp. 105-109 and 139-142.
Properties of modern zinc-base alloys, their constitution and ageing changes. Bibliography.

DIE-CASTINGS IN AUTOMOTIVE APPLICATIONS. By C. R. Maxon. "Metal Industry," London, 1937; vol. 50, pp. 551-554.
Use of zinc alloy pressure castings for radiator grilles, steering-wheel hubs, wind shield and window frames. Finishes in zinc die-castings.

ZINC ALLOY DIE-CASTING—AN INDUSTRIAL ACHIEVEMENT. By W. W. Broughton. "Metal Progress," April, 1938; pp. 381-386.
Modern die-casting alloys, properties and applications.

ZINC DIE-CASTINGS. SOME NOTES ON THEIR USE IN THE AMERICAN AUTOMOBILE INDUSTRY. By Herbert Chase. "Automobile Engineer," 1938; vol. 28, pp. 180-182.
Radiator grilles and other automobile fittings.

DIE-CASTINGS GAIN GROUND IN HARDWARE PRODUCTION. By Herbert Chase. "Iron Age," 1938; vol. 142 (3), pp. 33-36.
Describes the die-casting production at an American plant using zinc-base alloy.

DIE-CASTING A TURNCOCK ASSEMBLY. By E. Stevan. "Machinist," 1938; vol. 82 (43), p. 585 (E).
Turncocks for oil-kegs produced from assembly of 5 zinc alloy pressure castings, made from a multiple tool.

DIE-CASTING SETS NEW PACE IN 1938 MODELS. By Herbert Chase. "Automotive Industries," 1938; vol. 78 (3), pp. 78-85 and 92.
Zinc alloys for radiator grilles, glove compartments, louvres, running-board end fittings, gear shift lever, etc. Machining of die-castings. New finishes. Physical properties.

BANJO TYPE 20% OF STEERING-WHEEL PRODUCTION. By Herbert Chase. "Automotive Industries," 1938; vol. 78 (7), pp. 200-203 and 210.
Construction of steering-wheels at General Motors, using zinc alloy pressure die-castings.

'39 CARS USE MORE DIE-CASTINGS. By Herbert Chase. "Automotive Industries," 1938, vol. 79 (25), pp. 794-799.
Illustrated review describing zinc alloy pressure castings for grilles, headlamp bezels, window-frames, etc.

## LIGHT ALLOYS

DEVELOPMENTS IN ALUMINIUM ALLOY DIE-CASTING. "Machinery," London, 1933; vol. 42, pp. 61-66 and 121-123.
Pressure and gravity production at Birmingham Aluminium Casting Company (1903) Limited. Applications, alloys, die-making and die-casting practice are described.

DIFFICULTIES OF DIE-CASTING PURE ALUMINIUM. Anon. "Metal Industry," London, 1934; vol. 44, pp. 627-630.
Difficulties in the die-casting of aluminium due to hot shortness and absence of freezing range which prevents feeding. Slight alloying additions improve die-castability.

' Tech-

with 12%
silicon and its derivatives are discussed in detail. Bibliography.

THE DIE-CASTING OF NON-FERROUS METALS (III). ALUMINIUM DIE-CASTINGS. By Freeman Horn. "Metal Industry," London, 1935; vol. 46, pp. 63-65.
Gravity and pressure casting in various aluminium alloys. Heat treatment.

AN INVESTIGATION OF ALUMINIUM DIE-CASTING ALLOYS. Nos. IVa and Va. By E. E. Thum. Proc. Amer. Soc. Test. Mat., 1935; vol. 35 (1), pp. 184-189.
Testing and properties of American die-cast alloys.

ALUMINIUM DIE-CASTINGS AND THEIR FIELD OF USEFULNESS IN THE TELEPHONE INDUSTRY. By François Van Laetham. "Electrical Communication," 1935; vol. 14, pp. 121-132.
Aluminium pressure process described and application to selector frames, finger plates, subscriber set housing, etc.

THE TECHNOLOGY OF THE LIGHT DIE-CASTING ALLOYS-THEIR USES IN AUTOMOBILE CONSTRUCTION. "Foundry Trade Journal," 1936; vol. 54, p. 420.
Summary of paper by A. Dumas given to Soc. Ing. Automobile, France, 1935; vol. 8 (4), pp. 199-206.

ALUMINIUM DIE-CASTINGS. By G. M. Rollason and Sam Tour. "Metals Handbook" (Amer. Soc. Met.), 1936; pp. 994-999.
Properties, machining and finishing of aluminium alloy die-castings.

"WINDING" THE ROTORS FOR SQUIRREL CAGE MOTORS BY CASTING. By Frank S. Dobric. "Metal Industry," New York, 1937; vol. 35 (5), pp. 210-211.
Illustrated description of pressure die-casting as applied to rotor rings.

ALUMINIUM DIE-CASTING. By Arthur Street. "Metallurgia," 1938; vol. 17 (100), pp. 140-142.
Review of gravity and pressure die-casting with emphasis on aluminium-silicon alloy.

ACHIEVEMENTS WITH ALUMINIUM ALLOY CYLINDER HEADS. "Light Metals," 1938; vol. 1, No. 11, pp. 412-413.
Advantages of using die-cast cylinder heads in aluminium alloy. Improvements in performance, petrol consumption are given.

DIE-CASTING ELEKTRON METAL. Anon. "Machinery," London, 1936; vol. 48, pp. 623-624.
Melting, production and design of parts for die-casting.

DIES FOR MAGNESIUM DIE-CASTING. Anon. "Machinery," London, 1937; vol. 49, pp. 721-722.
Water-cooled die described and illustrated.

## COPPER-BASE ALLOYS

BRASS PRESSURE CASTINGS AS PRODUCED ECONOMICALLY. By William W. Serg. "Iron Age," 1933; vol. 132, pp. 16-19.
Production of pressure castings in brass by use of Polak high-pressure machines. Physical properties, die life and production costs are also discussed.

COPPER ALLOY DIE-CASTINGS. By Allen F. Clark. "Machine Design," 1934; vol. 6 (11), pp. 24-26.
Design considerations for copper alloy die-castings. Suitable sections, draughts, size of cored holes are recommended. Discusses casting of threads, undercuts, etc.

RECENT DEVELOPMENTS IN BRASS DIE-CASTING METHODS. By Herbert Chase. "Machinery," New York, 1934; vol. 40, pp. 653-655.
Production at the Titan Metal Manufacturing Company, of America, using Polak machines. Die steels and suitable brasses are discussed.

A MILLION AND A HALF BRASS DIE-CASTINGS YEARLY. By Chas. O. Herb. "Machinery," New York, 1936; vol. 42 (6), pp. 361-366.
Use of the Polak high-pressure machine for die-casting brass.

THE DIES USED IN BRASS DIE-CASTING. By Chas. O. Herb. "Machinery," New York, 1936; vol. 42 (10), pp. 638-640.
Continuation of above. Die steels are discussed and some typical dies illustrated.

PRESSURE DIE-CASTINGS IN BRASS. By Herbert Chase. "Iron Age," 1936; vol. 137, pp. 40-41 and 103-105.
Pressure casting in copper-base alloys, including Doler brass (1% silicon), Brastil (5% silicon), etc.

BRASS DIE-CASTINGS. By J. C. Fox. "Metal Industry," London, 1938; vol. 52 (11), pp. 316-320.
Pressure casting using Polak machine. Die steels, design of castings, composition of suitable brasses and properties are given.

ALUMINIUM BRONZE. By Frank Hudson. "Foundry Trade Journal," 1933; vol. 48, pp. 86-89, 106-107, 121-123.
Paper to Scottish Local Section Inst. of Met. Structure and properties of the aluminium bronzes (not necessarily die-cast). Heat treatment.

"ALUMINIUM BRONZE" IMPROVED BY VACUUM DIE-CASTING. Anon. "Iron Age," 1934; vol. 133 (4), p. 29.
Method of die-casting aluminium bronze by drawing it by vacuum into a steel mould so that the metal rises tranquilly into the die.

THE DIE-CASTING OF NON-FERROUS ALLOYS. (1) DIE-CASTING OF YELLOW METAL. By A. H. Mundey. "Metal Industry," London, 1935; vol. 46, pp. 59-61.
Gravity cast aluminium bronze and pressure cast 60/40 brass.

THE CASTING OF ALUMINIUM BRONZE—PERMANENT MOULD CASTING. By H. J. Miller. "Metal Industry," London, 1938; vol. 53 (9), pp. 199-202.
Application, properties and production of aluminium bronze gravity castings.

## HIGH-MELTING-POINT ALLOYS

DIE-CASTING IRON AND STEEL. By A. W. Morris and Herbert R. Simmons. "Iron Age," 1933; vol. 131, pp. 665-666 and 1028-1030.
Description of pressure die-cast automobile camshafts. Compositions of various die-castable irons are given.

NOW-CAST-IRON DIE-CASTINGS. By Charles O. Herb. "Machinery," New York, 1936; vol. 42, pp. 569-574.
Wetherill process for pressure casting cast iron.

RECENT DEVELOPMENTS IN PRESSURE DIE-CASTING. Anon. "Machinery," London, 1936; vol. 47, pp. 529-531.
Pressure casting of nickel-silver spoon and fork blanks by the Schuler-Polak process.

DIE-CASTING MACHINES FOR HIGH MELTING-POINT ALLOYS. Anon. "Metal Industry," London, 1937 (50), pp. 217-218.
Description of Buhler die-casting machine.

COUNTER GRAVITY DIE-CASTING OF HIGH MELTING-POINT METALS. By Samuel P. Wetherill. "Jnl. Franklin Inst." 1937; vol. 224 (2), pp. 153-190.
Die-casting of high melting-point alloys (mainly cast iron) as carried out by Wetherill Engineering Company, of U.S.A.

## MACHINING OF DIE-CASTINGS

STRIPPING DIE-CAST HANDLES. By E. S. "Mechanical World," 1937; vol. CII, pp. 390-391.
Tools for the final dressing of die-cast motor-car door handles.

FIXTURES FOR MACHINING DIE-CASTINGS. "Machinist," 1938; vol. 82 (5), pp. 51-53 (A).
Illustrated article describing jigs and machining practice for various pressure die-castings.

PRACTICE IN MACHINING DIE-CASTINGS. "Machinery," New York. Six instalments—October, 1937, to March, 1938.
Comprehensively deals with most machine operations on zinc alloy die-castings (same series published "Machinery's" Die-casting Supplement, March-July-October, 1938, February-March-April, 1939).

MACHINING DIE-CASTINGS. Anon. "Steel," 1938; vol. 102 (24), pp. 34-37.
Illustrated article describing methods at Doehler Die-casting Company, for machining bulk quantities of die-castings.

ACCESSORY TOOLS FOR DIE-CASTING PRODUCTION. By Herbert Chase. "Machinist," 1938; vol. 82 (17), pp. 372-374 (A).
Zinc alloy die-castings at Continental Die-casting Corporation of U.S.A. Casting, trimming, inspection and machining.

MODERN PRACTICE IN MACHINING LIGHT METALS. Anon. "Light Metals" vol. 2 (19) pp. 265-270.
First of a series of articles which are to deal with all major operations involved in the machining of light metals. Particular attention is paid to tool forms and materials and to operating conditions.

## PLATING OF DIE-CASTINGS

PLATING ZINC ALLOY DIE-CASTINGS. By E. A. Anderson. "Metal Industry," London, 1938; vol. 53 (5), pp. 111-113.
Report of the procedure of a number of American platers.

PLATING PRACTICE ON ZINC DIE-CASTINGS. By B. F. Robinson. "Machinist," 1938; vol. 82 (21), pp. 468-470 (A).
Plating methods carried out at Continental Die-casting Corporation of U.S.A.

PLATING ZINC ALLOY DIE-CASTINGS, COMMERCIALLY. "Metal Cleaning and Finishing," 1938, July to October (4 instalments).

ELECTROPLATING OF ALUMINIUM. Proc. Amer. Soc. Test. Mat., 1934; vol. 34. Report of Committee B.7 (Appendix).
Describes plating methods.

PRODUCTION OF ELECTRO DEPOSITS ON ALUMINIUM AND ITS ALLOYS. Anon. "Light Metals," 1938; vol. 1 (9), pp. 314-316 and (10) 368-371.
Describes various methods, not necessarily deposition on die-castings.

## OTHER FINISHES

SUCCESSFUL FINISHING ON DIE-CASTINGS. By Edgar Parkinson and Frank B. Faulhaber. "Iron Age," 1933; vol. 131, p. 783.
Baked finishes on various die-casting alloys.

FINISHING ZINC AND ALUMINIUM DIE-CASTINGS. By Herbert Chase. "Machinery," New York, 1935; vol. 42, pp. 120-122, 181-184.
Two articles which describe the majority of finishes for die-castings, including plating and organic finishes. An estimate of the relative costs of various processes is given.

FINISHING OF DIE-CASTINGS. By J. C. Fox. Amer. Soc. Test. Mat., 1936 (Appendix II).
Report of Committee B.6 on die-cast metals and alloys. A comprehensive survey of the finishing of aluminium and zinc-base die-castings.

CHEMICAL COLOURING OF METALS. By J. W. Perring. Paper read before Electro Depositors Technical Society, Northampton Polytechnic Institute, Clerkenwell, London, E.C.1. February 12, 1936. "Jnl. Electro Depositors Tech. Soc.," 1936; vol. 11, pp. 75-86.
The reprint of this lecture gives a number of chemical finishes, many of which are suitable for die-castings.

THE COLOURING OF METALS, IV: ZINC AND DIE-CASTINGS. By Herbert R. Simmonds and C. B. Young. "Iron Age," 1936; vol. 138 (10), pp. 30-35, 110.
The authors deal firstly with chemical finishes, then with the "Cronak Process" for protecting the surface of zinc-base die-castings from corrosion, and finally with the plating of die-castings.

DECORATIVE FINISHES FOR ZINC ALLOY DIE-CASTINGS. By R. E. Kellers. "Products Finishing," 1937; vol. 2 (3), pp. 22-23.
Describes a photo-lithographic process for producing a grained effect.

BURNISHING OF ZINC DIE-CASTINGS. By Herbert Chase. "Machinist," 1937; vol. 81 (8), pp. 196-197.
Various stages in burnishing of die-castings.

ORGANIC FINISHES ON ZINC-BASE DIE-CASTINGS. By E. E. Halls. "Metal Treatment," 1938 (autumn); vol. 4 (15), pp. 115-119.
Besides discussing enamels, etc., the article goes fully into the subject of pre-treatment before finishing.

THE USE OF OXIDE FILMS ON ALUMINIUM AND ITS ALLOYS. By E. G. West. "Metallurgia," 1938; vol. 17, pp. 137-139 and 197-199.

PRACTICAL ASPECTS OF ANODISING TECHNIQUE. By V. F. Henley. "Light Metals"; vol. 1 (2), pp. 71-73 (3), 90-92.
Although the above two publications do not necessarily deal with anodising of die-castings they should be of value to those desiring information.

# INDEX